Isolation Studies using Standard RECO and Particle Flow

Marcello Maggi(1), Michele Pioppi(2), Alberto Ocampo(3)
(1)INFN Bari, (2)Imperial College, INFN Perugia, (3) Universidad de los Andes

Outline

- Introduction
- Technical details
- Lepton requirements
- Isolation calculation
- Leptons combined isolation
- Optimisation of Isolation requirements
- Optimisation approaches
- Single Lepton
- Same Sign Di-Leptons
- Opposite Sign Di-Leptons
- Conclusions

Introduction

"The pT spectrum of the resulting leptons depends strongly on the mass difference between the initial and final SUSY particles. For the cases in which the two SUSY particles are more nearly mass-degenerate, the lepton pT spectrum is expected to be soft, and therefore a high lepton reconstruction efficiency and background rejection at low transverse momentum is required." CMS AN 2009/167

What we are doing is an isolation study using soft leptons with PF2PAT and PAT. We want to go as low in Pt as we could. We basically are redoing the Isolation note CMS AN 2009/167.

Available on CMS information server **CMS AN 2009/167**

The Compact Muon Solenoid Experiment

Analysis Note

The content of this note is intended for CMS internal use and distribution only

November 20, 2009

Study of isolation properties of SUSY low-p_T leptons.

Z. Hatherell[a], G. Karapostoli[a], M. Pioppi[a,b], A. Savin[c], A. Sparrow[a], M. Weinberg[c]

a) Imperial College London, United Kingdom

b) INFN e Dipartimento di Fisica, Perugia, Italy

c) University of Wisconsin, Madison, United States

Abstract

Events with leptons in the final state will play a significant role in SUSY searches at initial LHC luminosities. The energy spectra of the leptons is expected to be soft, especially in models where the mass difference between the initial SUSY particle and the lightest SUSY particle is small. Optimization of isolation cuts for electrons in the transverse momentum range $5 < p_T < 30$ GeV and for muons in the range $3 < p_T < 30$ GeV is discussed. The results are presented in terms of SUSY lepton reconstruction efficiency and rejection of fake leptons and leptons from heavy quark decays.

Technical Details

PAT production

- CMSSW_3_1_4
- PAT Layer1 V6 recipe as appears at https://twiki.cern.ch/twiki/bin/view/CMS/SusyPatLayer1DefV6

PF2PAT production

- CMSSW_3_3_2
- PF2PAT recipe posted on Nov 17 2009 at https://twiki.cern.ch/twiki/bin/view/CMS/WorkBookPF2PAT#3_3_2

Samples Used

- /LM0/Summer09-MC_31X_V3_7TeV-v1/GEN-SIM-RECO
- /LM1/Summer09-MC_31X_V3_7TeV-v1/GEN-SIM-RECO
- /InclusiveBB_Pt30/Summer09-MC_31X_V3_7TeV-v1/GEN-SIM-RECO
- /QCD_Pt250to500-madgraph/Summer09-MC_31X_V3_7TeV_preproduction-v1/GEN-SIM-RECO
- /QCD_Pt500to1000-madgraph/Summer09-MC_31X_V3_7TeV_preproduction-v1/GEN-SIM-RECO
- /QCD_Pt1000toInf-madgraph/Summer09-MC_31X_V3_7TeV_preproduction-v2/GEN-SIM-RECO
- /TTbarJets-madgraph/Summer09-MC_31X_V3_7TeV-v2/GEN-SIM-RECO
- /WJets-madgraph/Summer09-MC_31X_V3_7TeV_preproduction-v1/GEN-SIM-RECO

Lepton requirements

Lepton classification based on MC

- "Prompt" leptons, originated by SUSY decay particles, a W/Z or a Tau.
- "Heavy Flavor" leptons, coming from hadronic decays of heavy flavor particles (b/c).
- "fake" leptons, did not have any corresponding lepton at the truth generated level.
- MC truth was done using a $\Delta R < 0.5$

$$\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2}$$

Electron Selection

- Satisfy RobustLoose
- $Pt > 2$ GeV
- $|\eta| < 2.5$
- Transverse impact corrected for the beam spot < 2mm

Muon Selection

- Satisfy RobustLoose
- $Pt > 2$ GeV
- $|\eta| < 2.1$
- Transverse impact corrected for the beam spot < 2mm
- Normalized global $\chi^2 < 10$
- Number of hits in the tracker track > 11

Isolation Calculation

Standard RECO

$$\mathrm{iso}_{\mathrm{abs}}^{\mathrm{track}} = \sum_{\Delta R<0.3} \mathrm{p}_T^{\mathrm{track}}$$

$$\mathrm{iso}_{\mathrm{abs}}^{\mathrm{ECAL}} = \sum_{\Delta R<x} \mathrm{E}_T^{\mathrm{ECAL}}$$

$$\mathrm{iso}_{\mathrm{abs}}^{\mathrm{HCAL}} = \sum_{\Delta R<x} \mathrm{E}_T^{\mathrm{HCAL}}$$

$$\mathrm{iso}_{\mathrm{abs}}^{\mathrm{comb}} = \sum_{\Delta R<0.3} \mathrm{p}_T^{\mathrm{track}} + \sum_{\Delta R<x} \mathrm{E}_T^{\mathrm{ECAL+HCAL}}$$

x = 0.3 for muons
x = 0.4 for electrons

Standard RECO

$$\frac{EcalIso + HcalIso + TrkIso}{p_T^{\mu}}$$

Particle Flow

$$\frac{\text{IsoChargedHadron + IsoNeutralHadron + isoPhoton}}{p_T^{\mu}}$$

Only tracks with pt grater than 1 GeV (200 MeV) are used to calculate iso track. Relative Isolation is defined as the ratio between absolute isolation and transverse momentum of the lepton.

Particle Flow

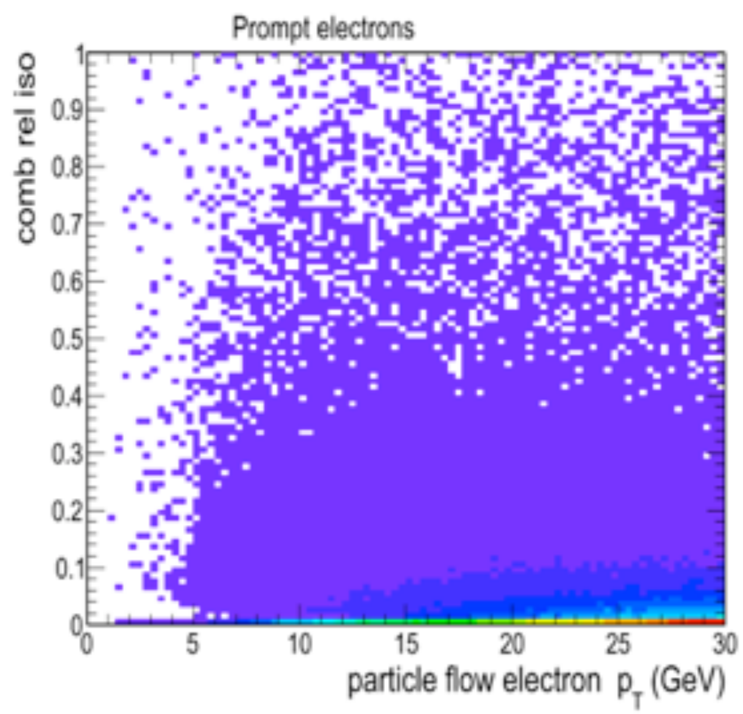
PF Neutral Hadrons
PF Charged Hadrons
PF Photons

A cone of ΔR < 0.4 around the lepton being considered is taken. Three different isolation quantities are calculated counting the deposits of pf neutral hadrons, pf charged hadrons, and pf photons inside this cone. A factor 1 is applied in the charged hadrons and photons cases, a 0.33 factor is applied for neutral hadrons. Relative combined Isolation is computed as the sum of the previous three quantities divided by the pt of the lepton.

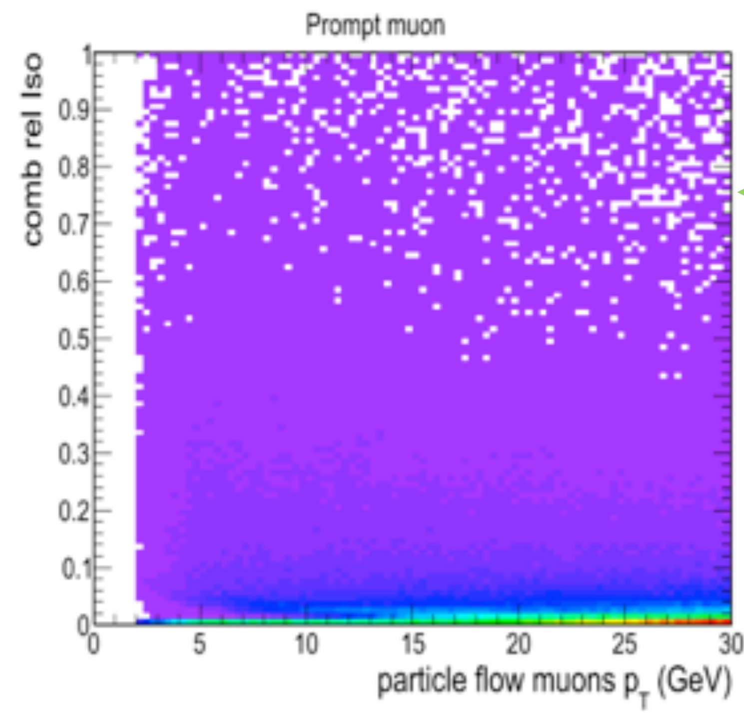
Lepton Combined Isolation

Prompt leptons

Electrons in a pt range of 2 to 30 GeV.



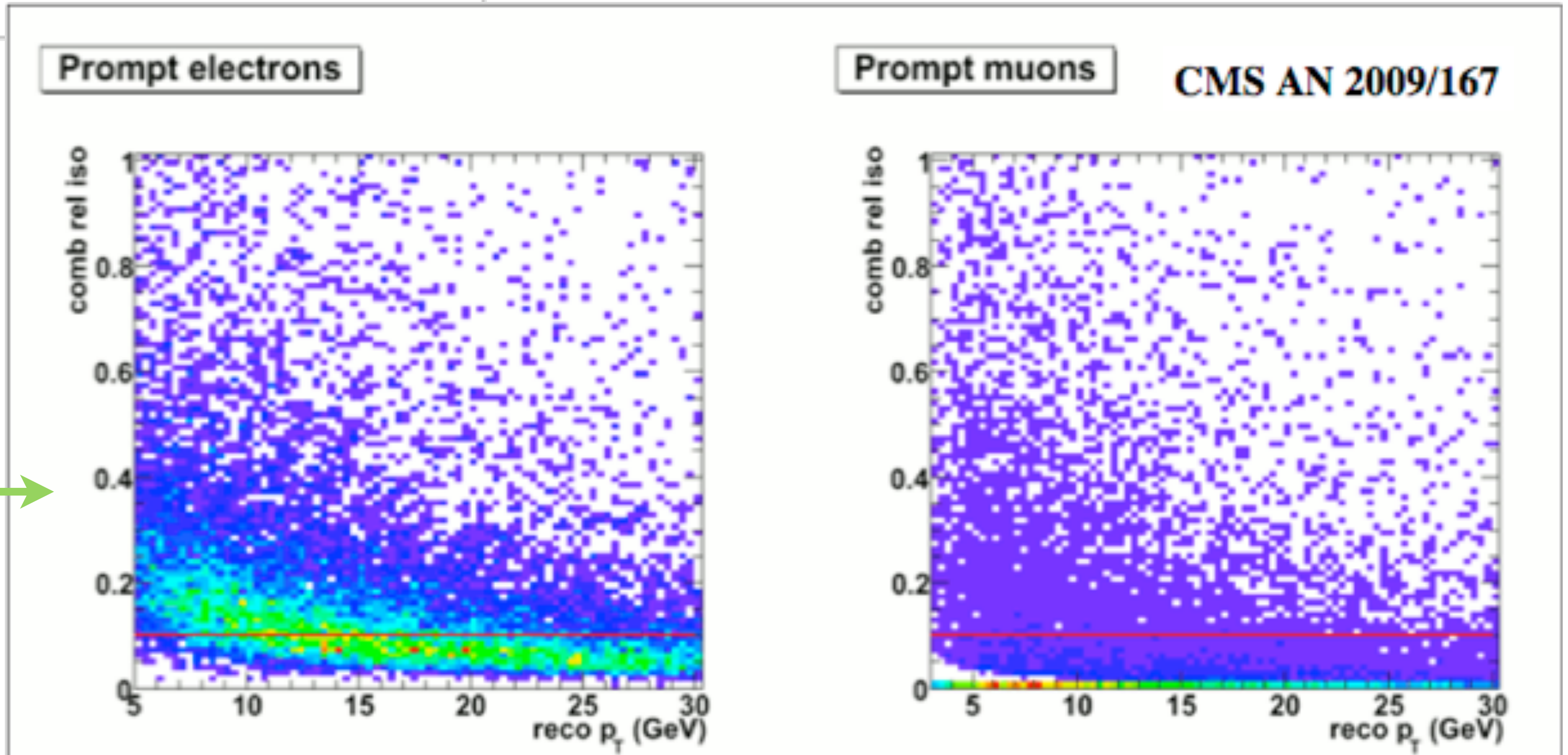
Muons in a pt range of 2 to 30 GeV.



Particle Flow

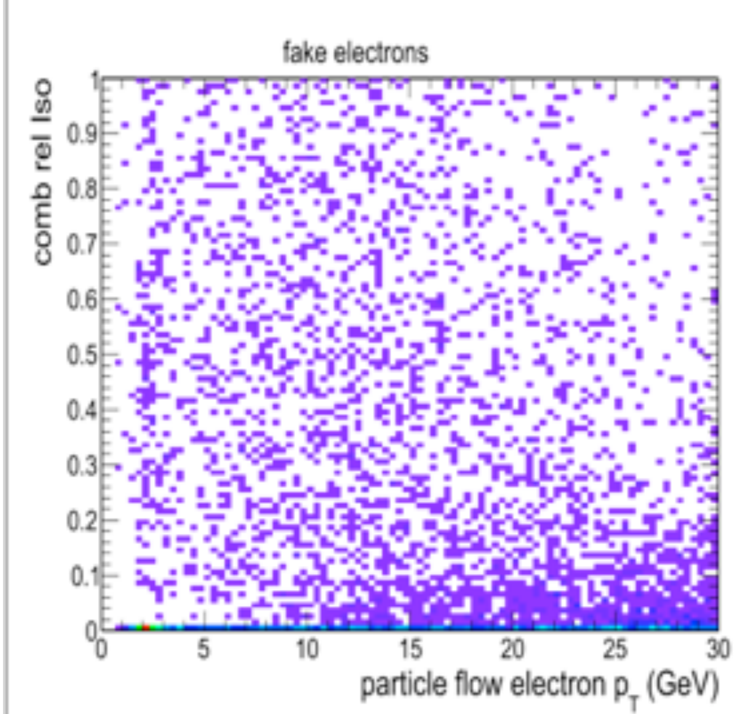
Differences between Particle Flow (PF) and Standard RECO are due to the way isolation is calculated. PF leptons are almost perfectly isolated.

Standard RECO

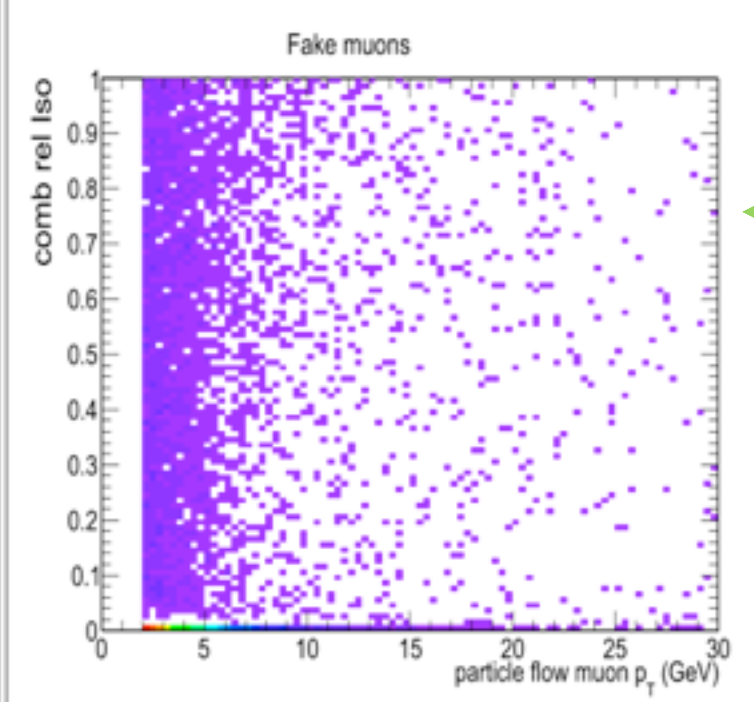


Fake Leptons

Electrons in a pt range of 2 to 30 GeV.

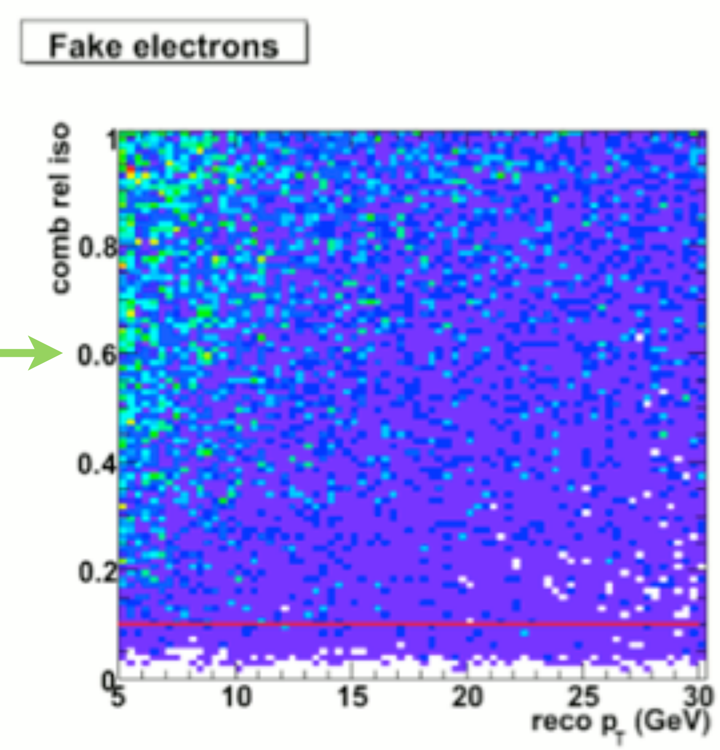


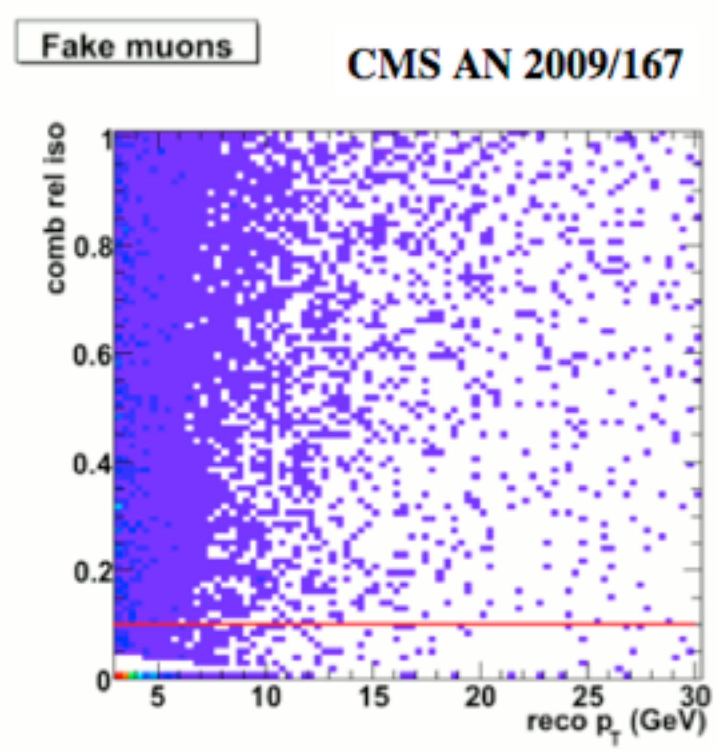
Muons in a pt range of 2 to 30 GeV.



Particle Flow

Combined Isolation vs pt for fake leptons PAT



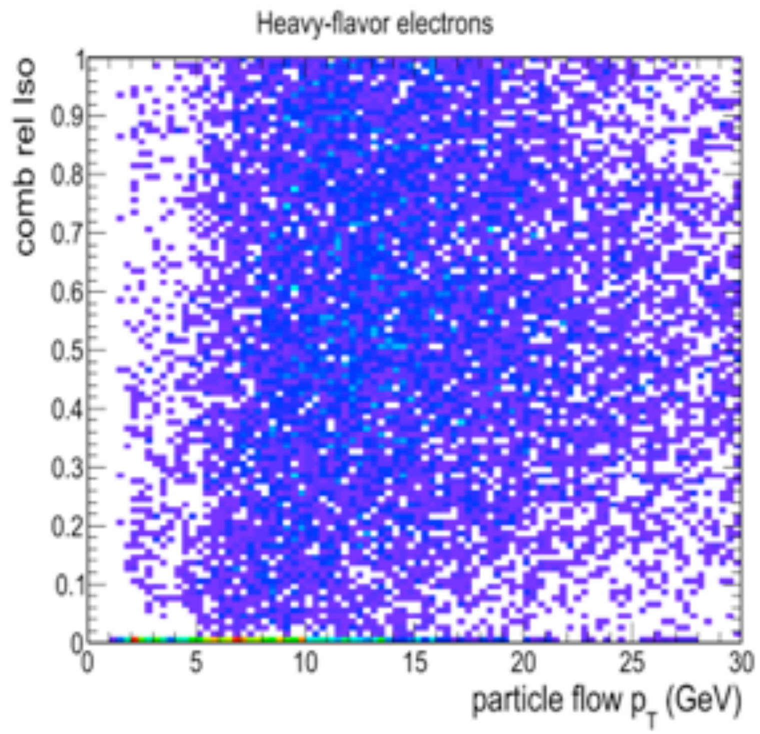


CMS AN 2009/167

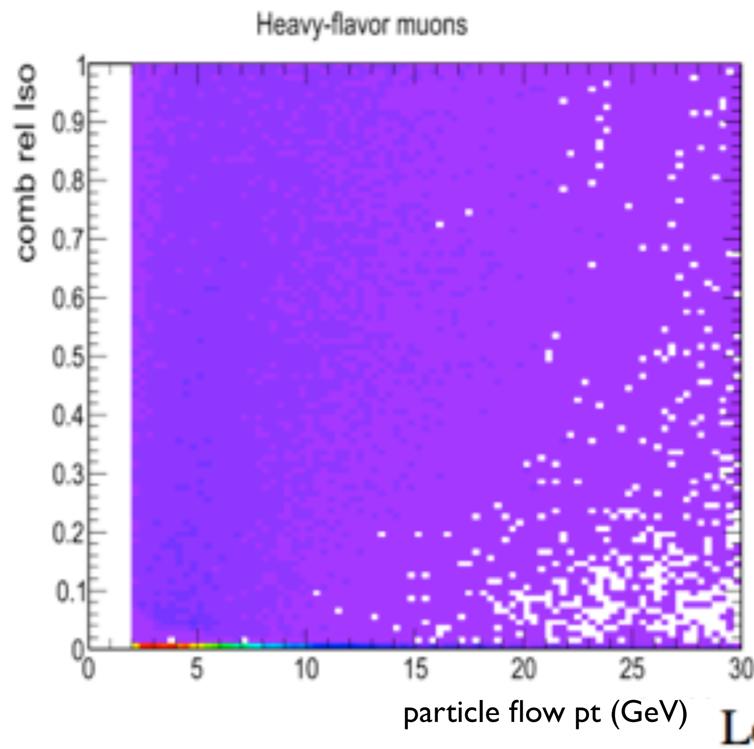
Standard RECO

Heavy Flavor

Electrons in a pt range of 2 to 30 GeV.



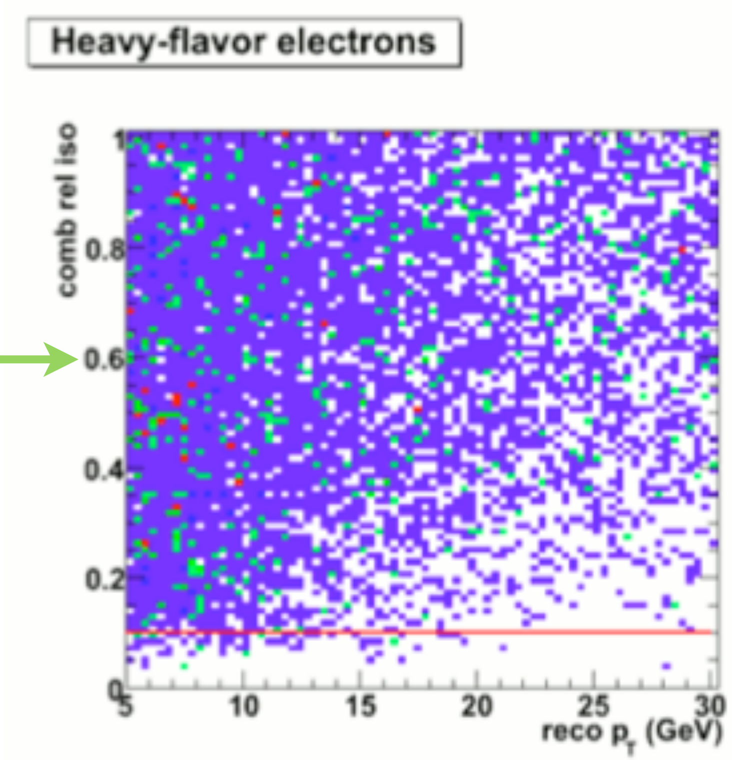
Muons in a pt range of 2 to 30 GeV.

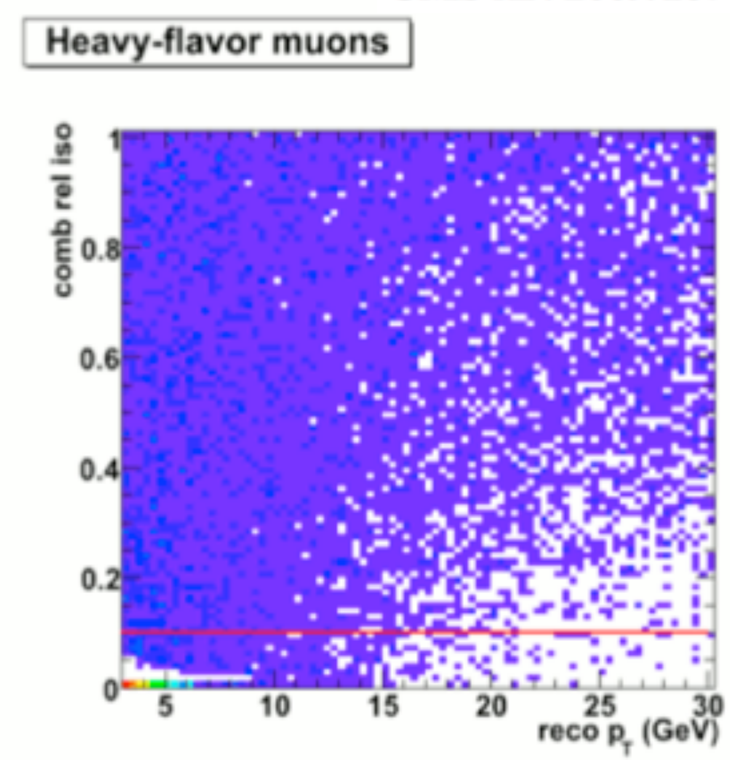


Particle Flow

Leptons in a pt range of 2 to 30 GeV.

CMS AN 2009/167





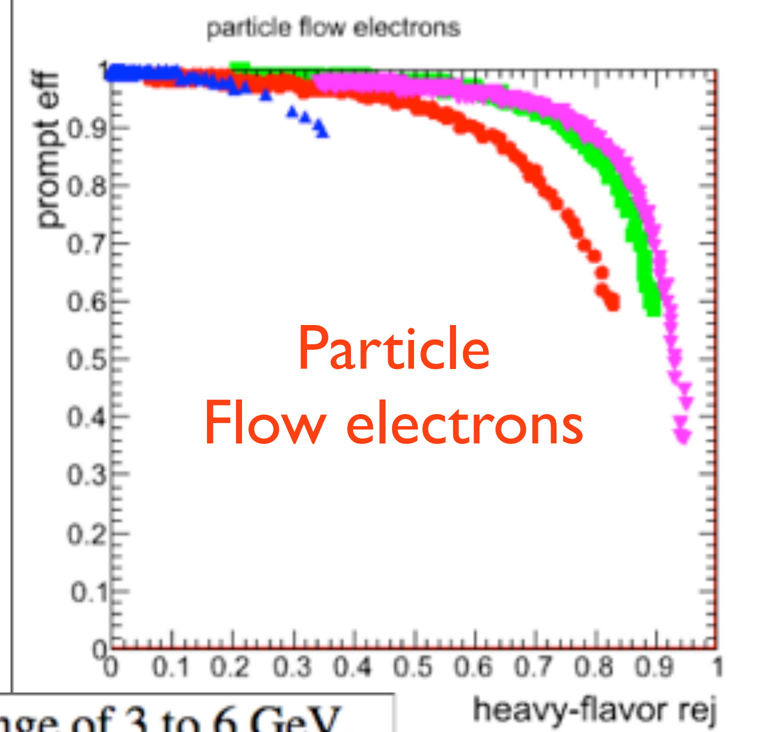
Standard RECO

Optimisation of Isolation requirements

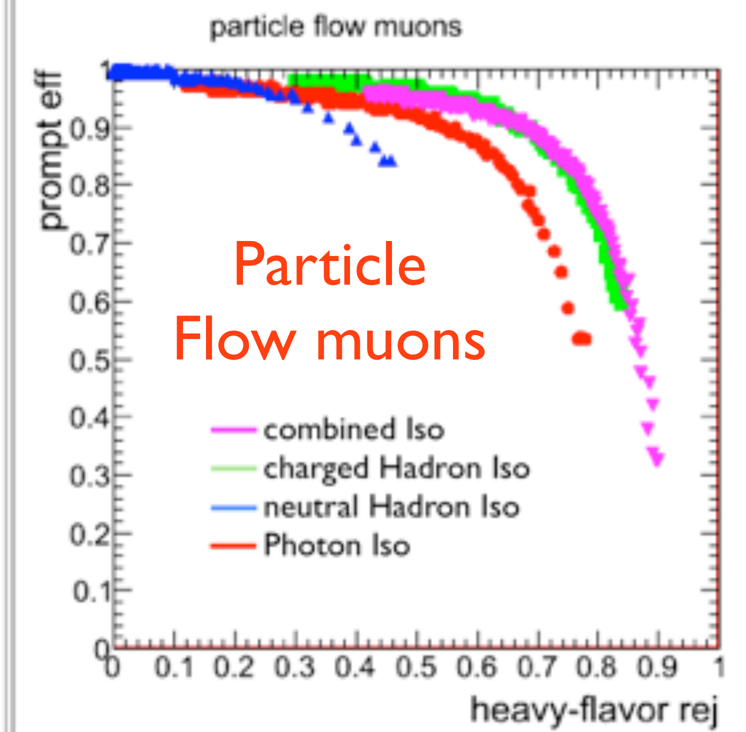
Heavy Flavour leptons

- We divided the leptons by their Pt in ranges from 0 to 3 GeV, 3 to 6 GeV 6 to 9 GeV .... and so on until 27 to 30 GeV.
- For each range of Pt, the efficiency of detection as function of the isolation variable was measured. From this measurement we obtained the rejection (1-eff) for “fake” and “Heavy Flavour” leptons.

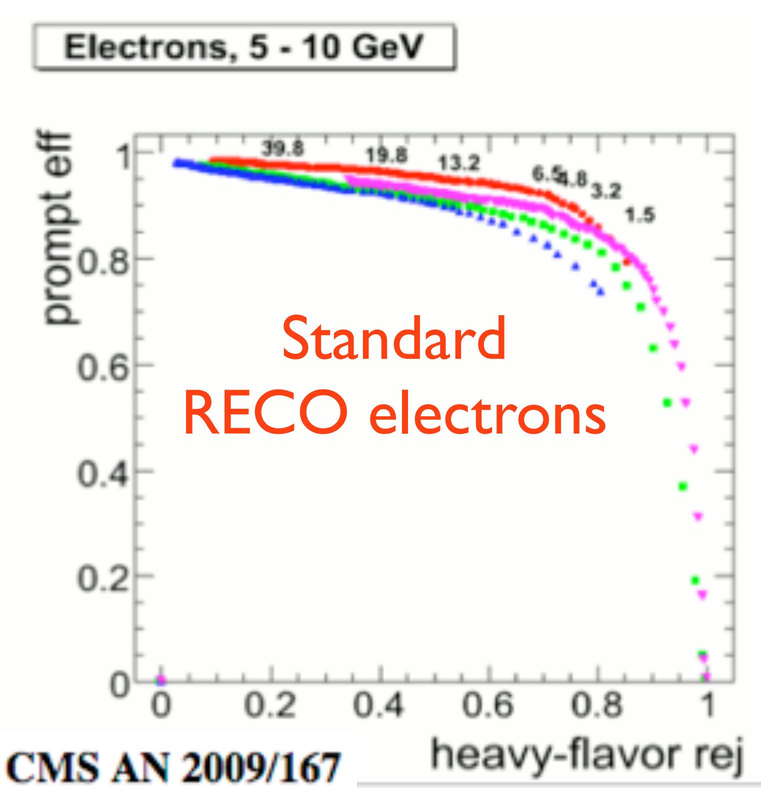
Electrons in a pt range of 2 to 10 GeV.



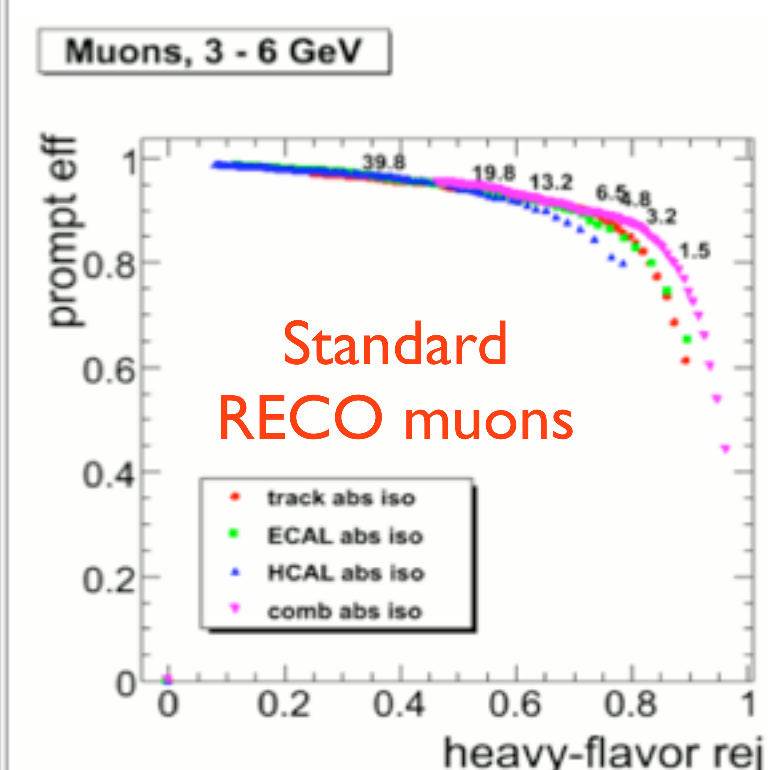
Muons in a pt range of 2 to 6 GeV.



Electrons in a pt range of 5 to 10 GeV.



Muons in a pt range of 3 to 6 GeV.

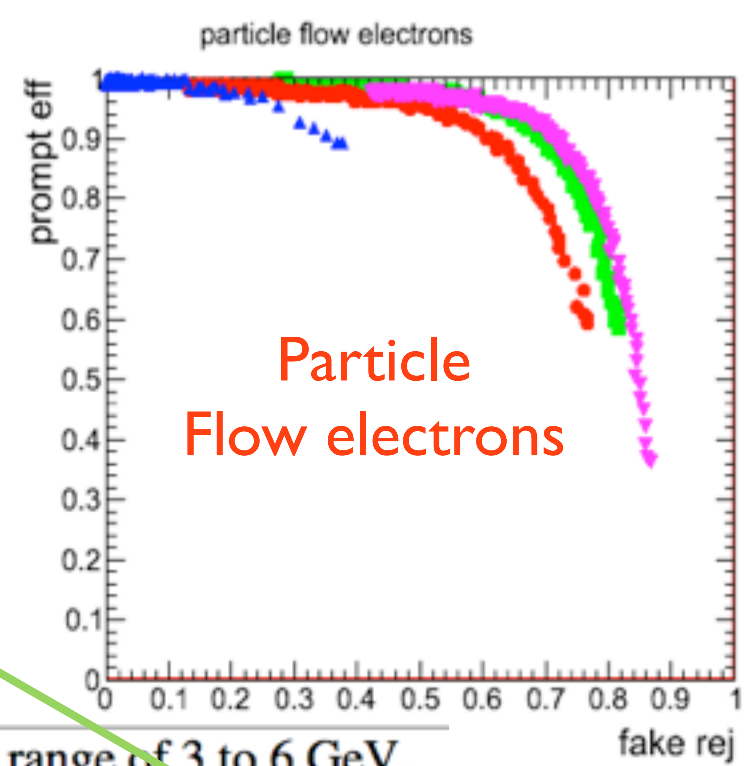


- Prompt leptons efficiency was plotted against fake and heavy flavour rejection.
- An additional cut of $H_T > 300$ was applied with all the reconstructed hadronic jets wit Pt bigger than 50 GeV. This was done to resemble the large multiplicity high-Et jet environment characteristic of SUSY.

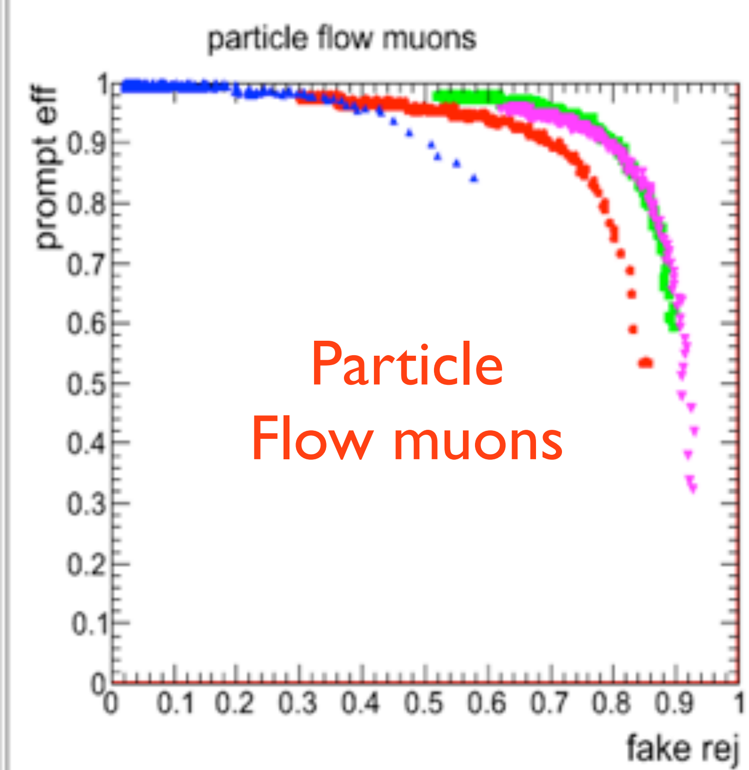
Fake Leptons

- For PF2PAT combined Isolation was used because it gives the best performance considering both rejection and efficiency for leptons.
- For PAT trackIso was used because of the same reason as previously
- Four optimisation approaches were considered in which the cut value for the isolation variable was searched:

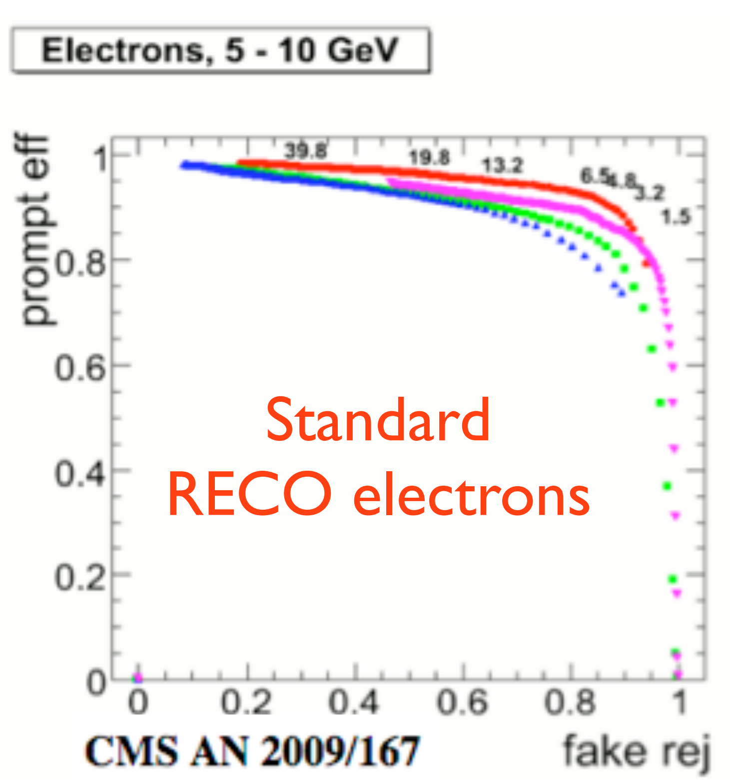
Electrons in a pt range of 2 to 10 GeV.



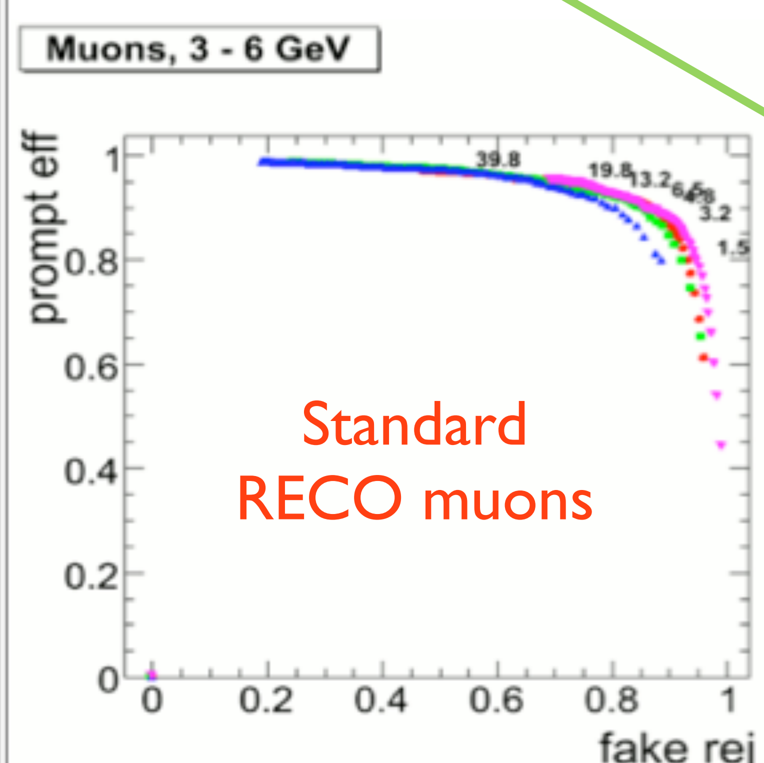
Muons in a pt range of 2 to 6 GeV.



Electrons in a pt range of 5 to 10 GeV.



Muons in a pt range of 3 to 6 GeV.



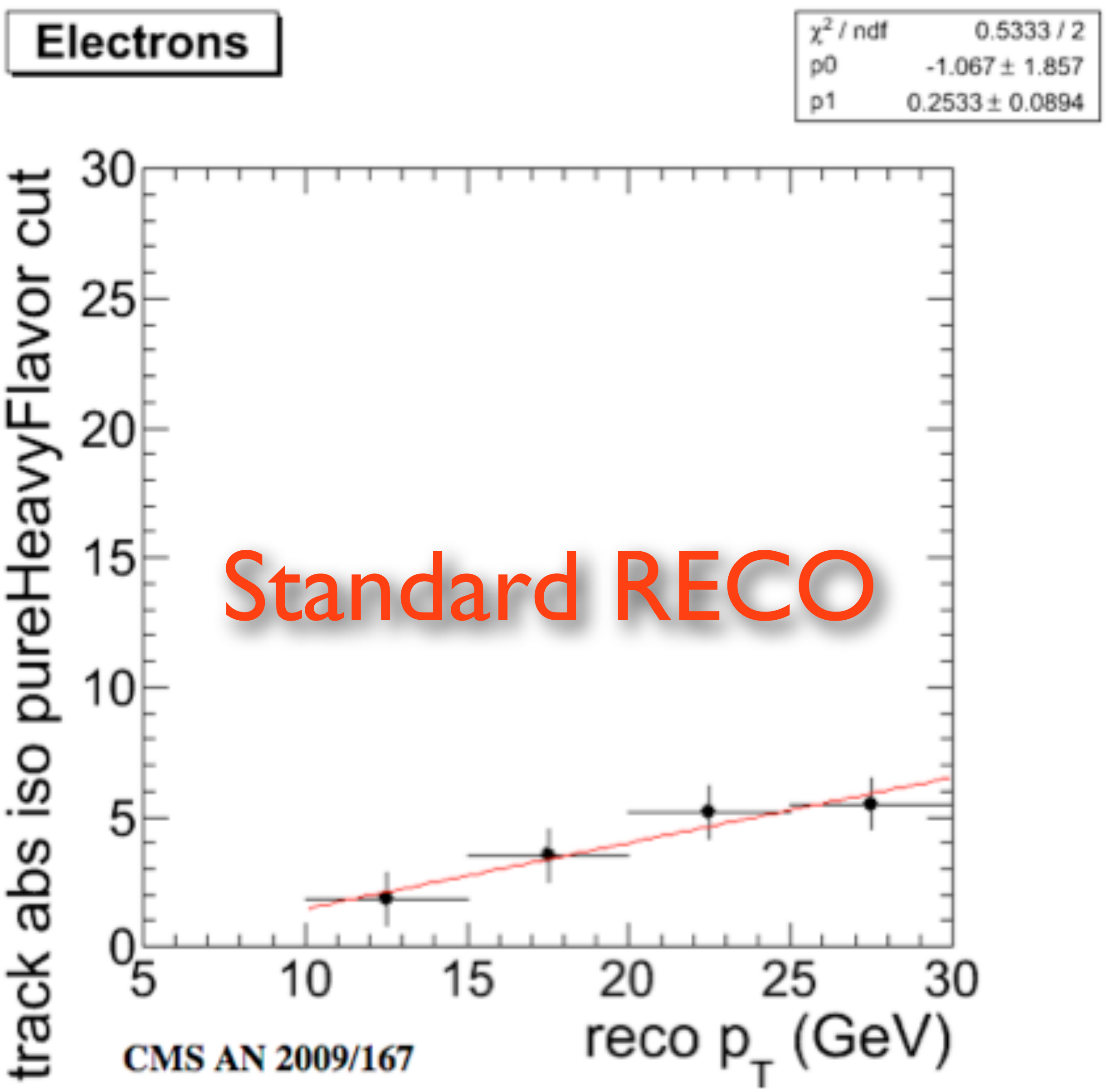
- **PureHeavyFlavor**
  Highest cut on isolation at which $\mathrm{rej}_{\text{heavy-flavor}} \geq 0.9$
- **PureFake**
  Highest cut on isolation at which $\mathrm{rej}_{\text{fake}} \geq 0.9$
- **Optimal**
  Minimizes $x = \sqrt{(1-\mathrm{eff})^2 + (1-\mathrm{rej}_{\text{fake}})^2}$
- **Efficient**
  Lowest cut on isolation at which $\mathrm{eff}_{\text{prompt}} \geq 0.9$

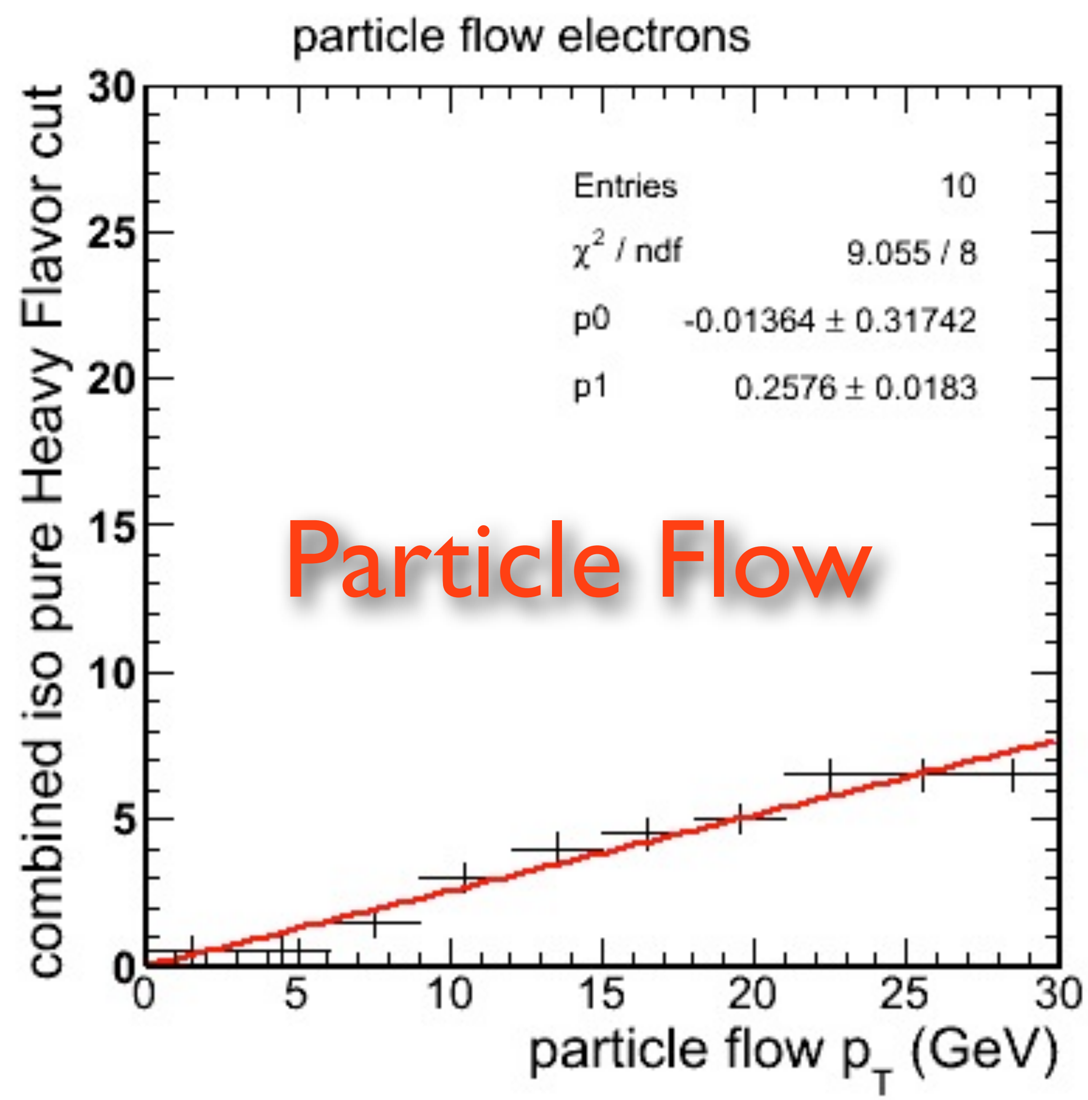
Four Optimisation Approaches

- **PureHeavyFlavor**
  Highest cut on isolation at which $\text{rej}_{\text{heavy-flavor}} \geq 0.9$
- **PureFake**
  Highest cut on isolation at which $\text{rej}_{\text{fake}} \geq 0.9$
- **Optimal**
  Minimizes $x = \sqrt{(1 - \text{eff})^2 + (1 - \text{rej}_{\text{fake}})^2}$
- **Efficient**
  Lowest cut on isolation at which $\text{eff}_{\text{prompt}} \geq 0.9$

Pure Heavy Flavour cut for electrons

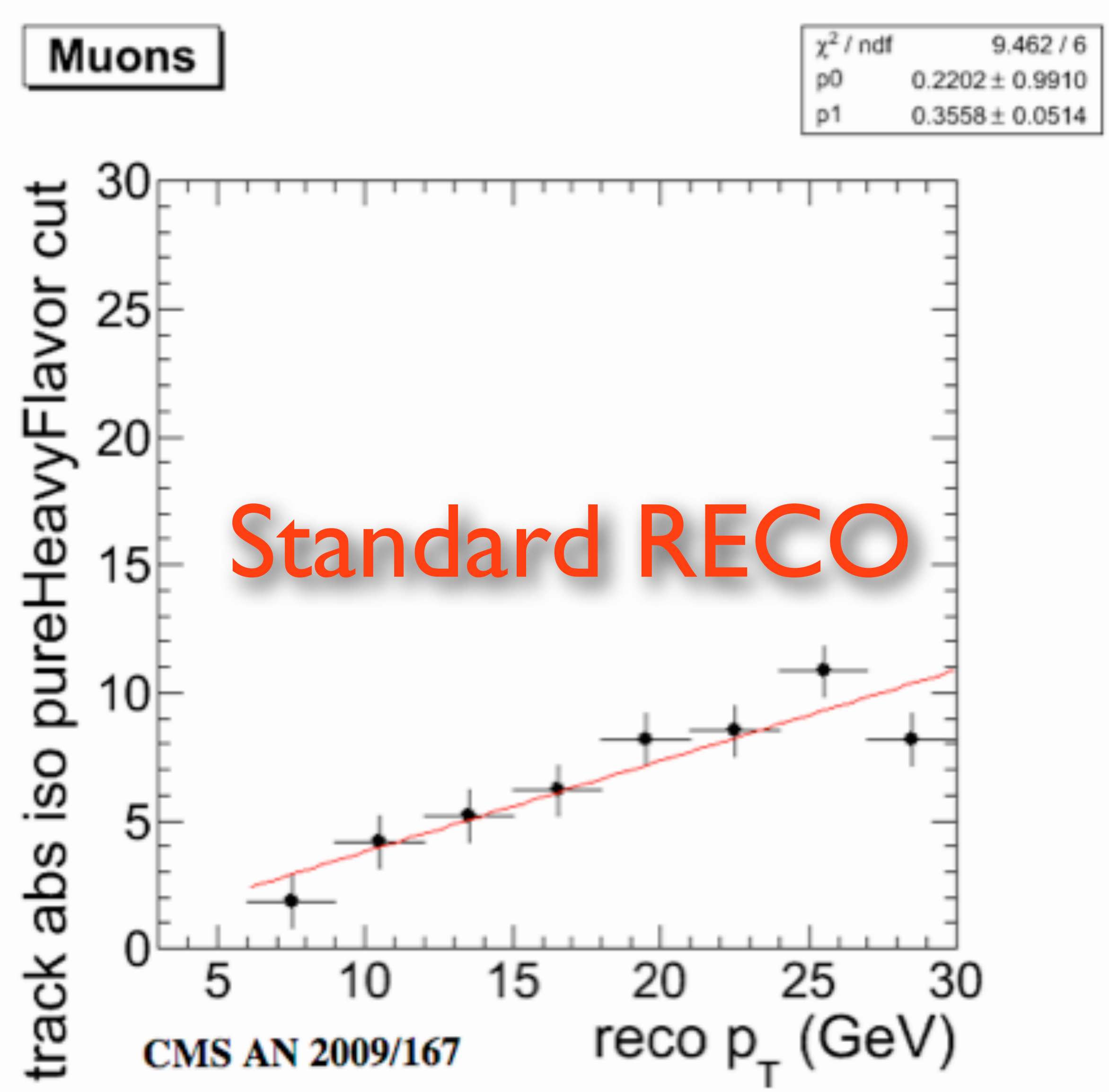
- **PureHeavyFlavor**
  Highest cut on isolation at which $\text{rej}_{\text{heavy-flavor}} \geq 0.9$

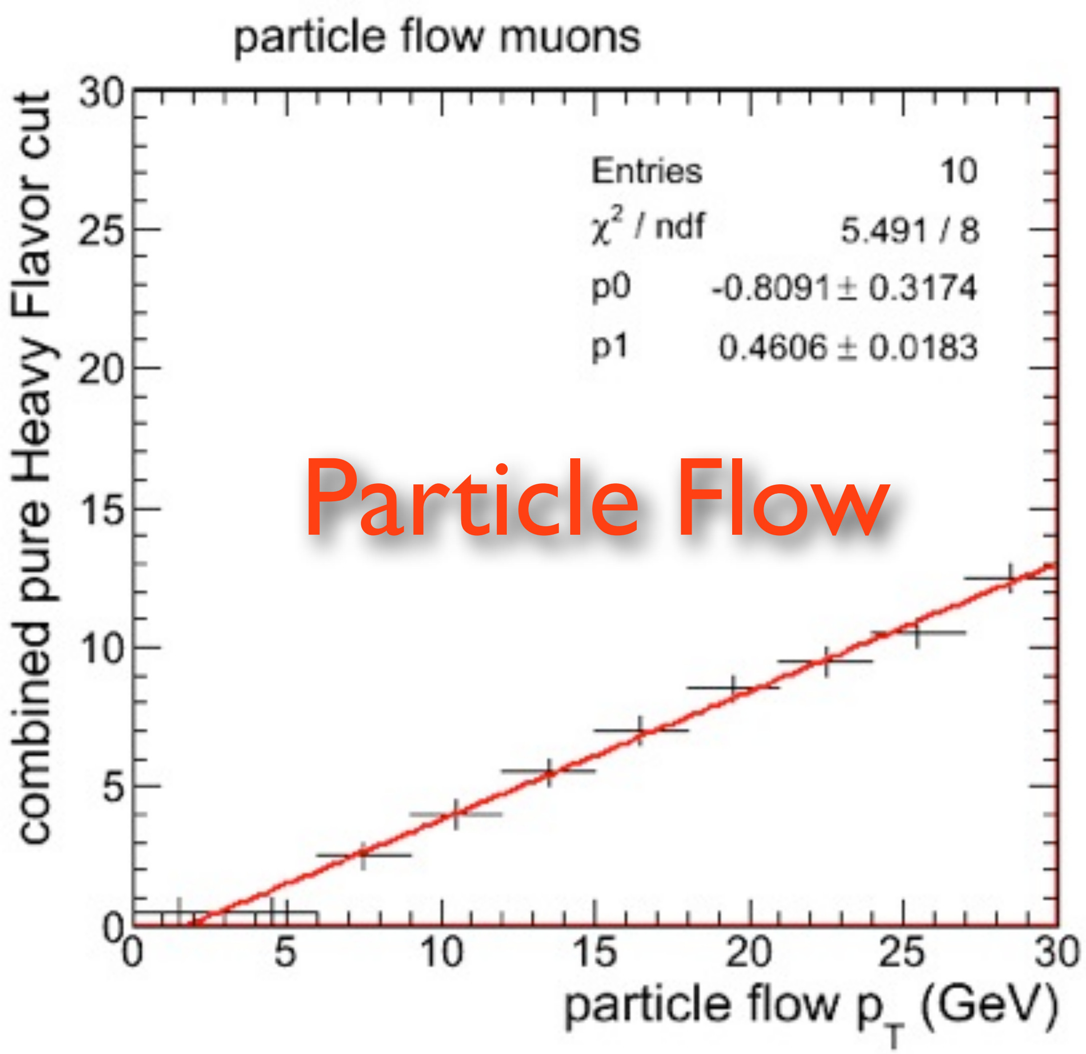




Pure Heavy Flavour cut for muons

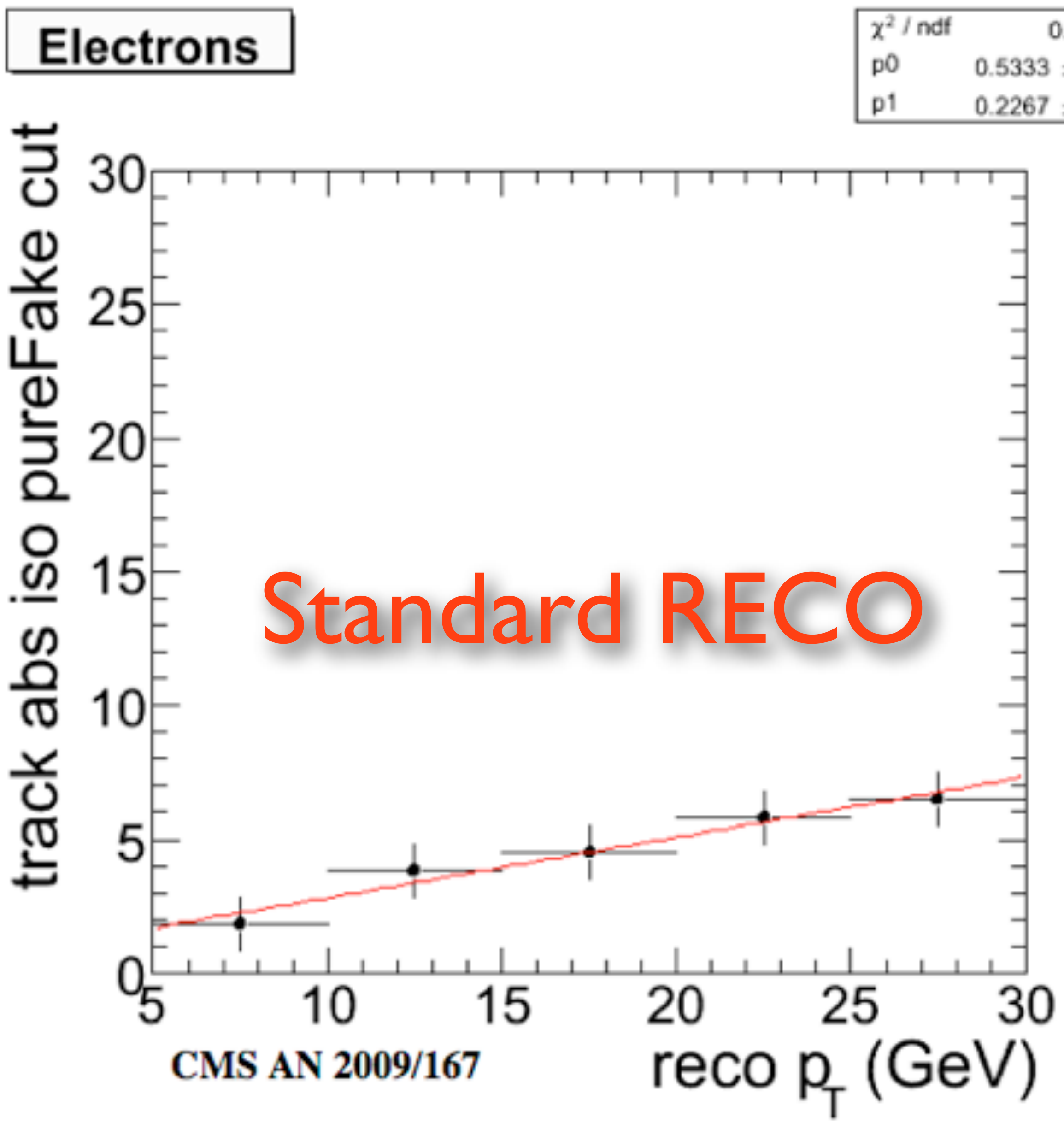
- **PureHeavyFlavor**
  Highest cut on isolation at which $\mathrm{rej}_{\text{heavy-flavor}} \geq 0.9$

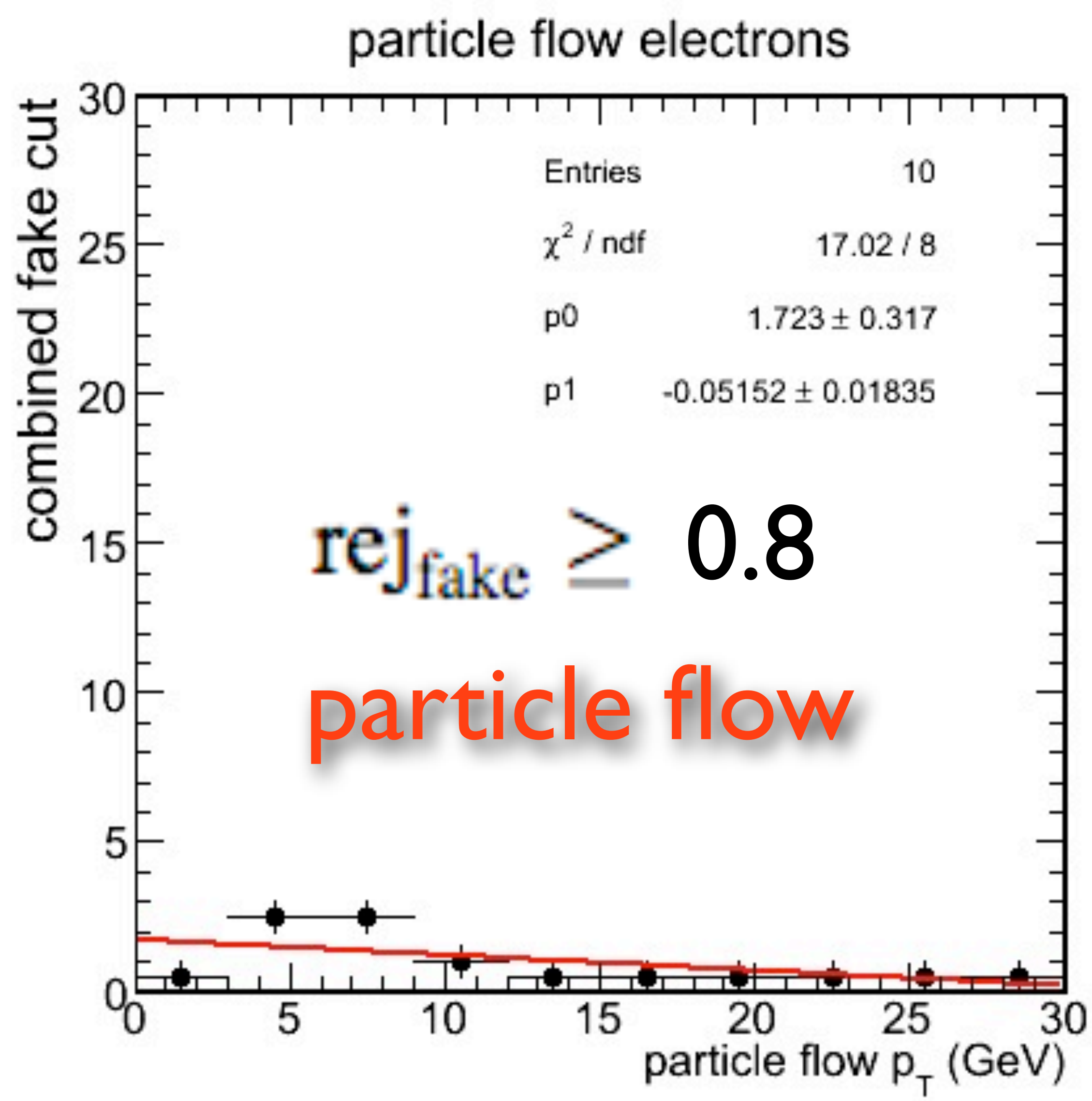




Pure Fake cut for electrons

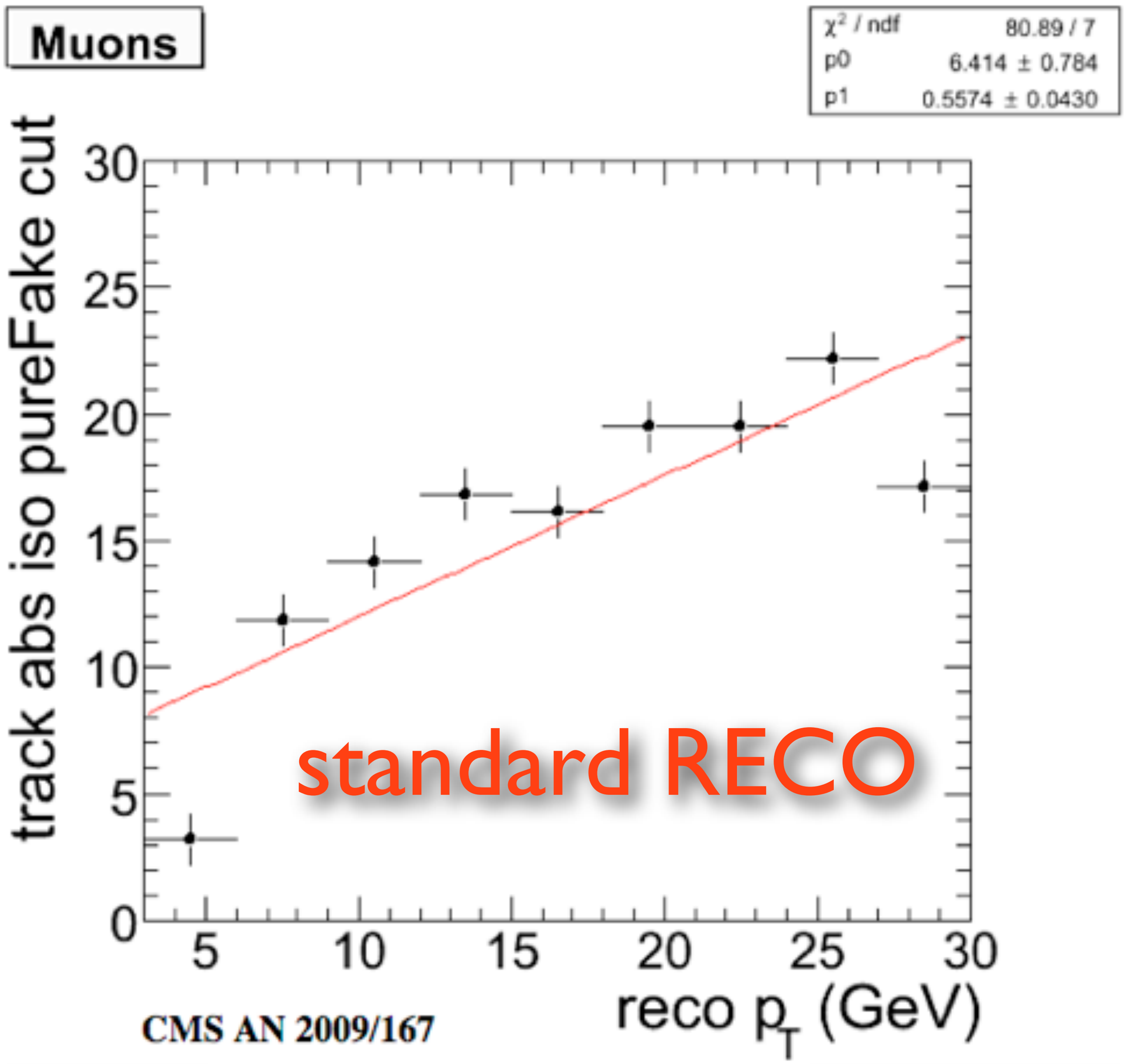
- **PureFake**
  Highest cut on isolation at which $rej_{fake} \geq 0.9$

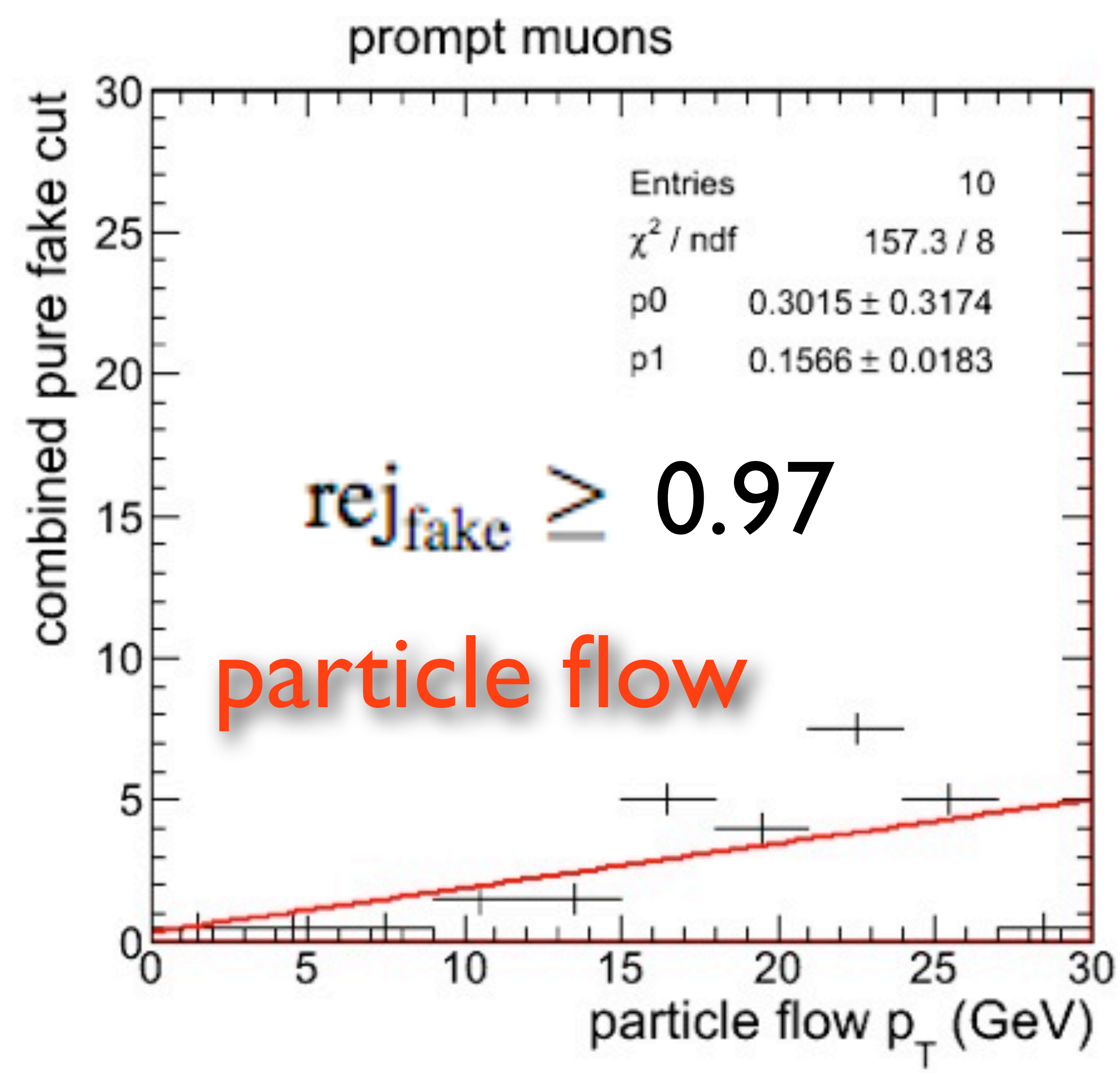




Pure Fake cut for muons

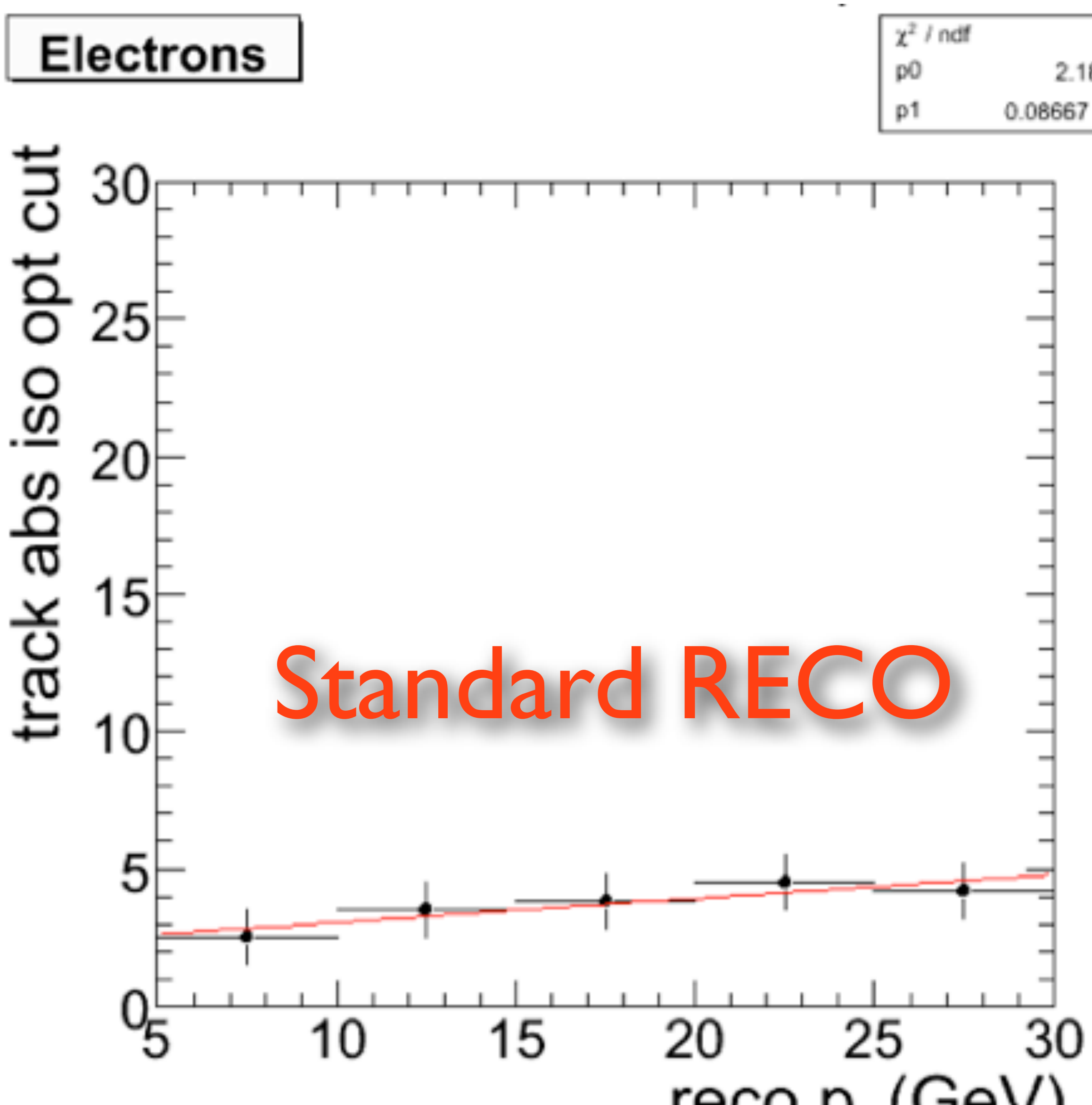
- **PureFake**
  Highest cut on isolation at which $rej_{fake} \geq 0.9$



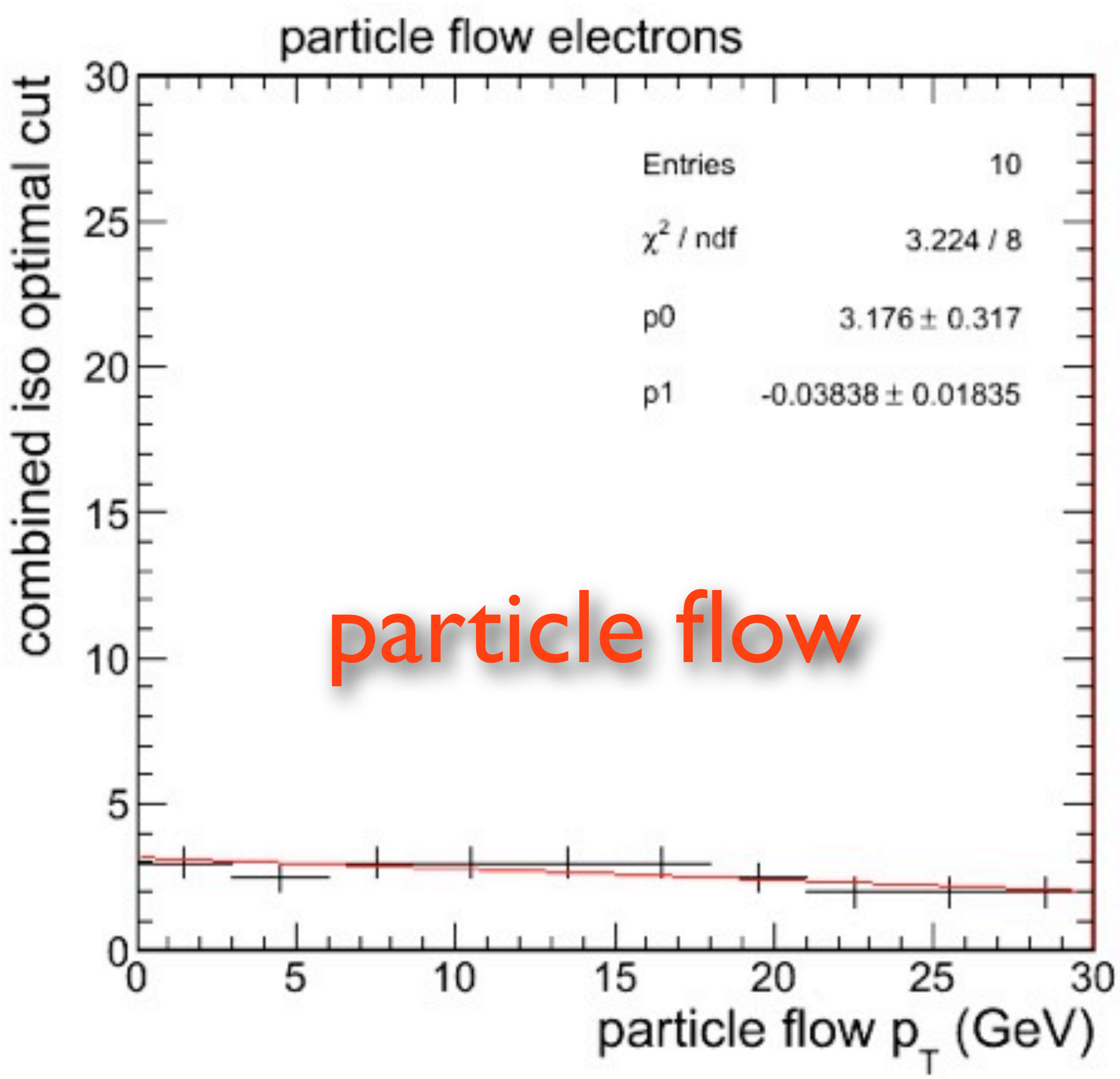


Optimal cut for electrons

- **Optimal**
  Minimizes $x = \sqrt{(1 - \text{eff})^2 + (1 - \text{rej}_{\text{fake}})^2}$

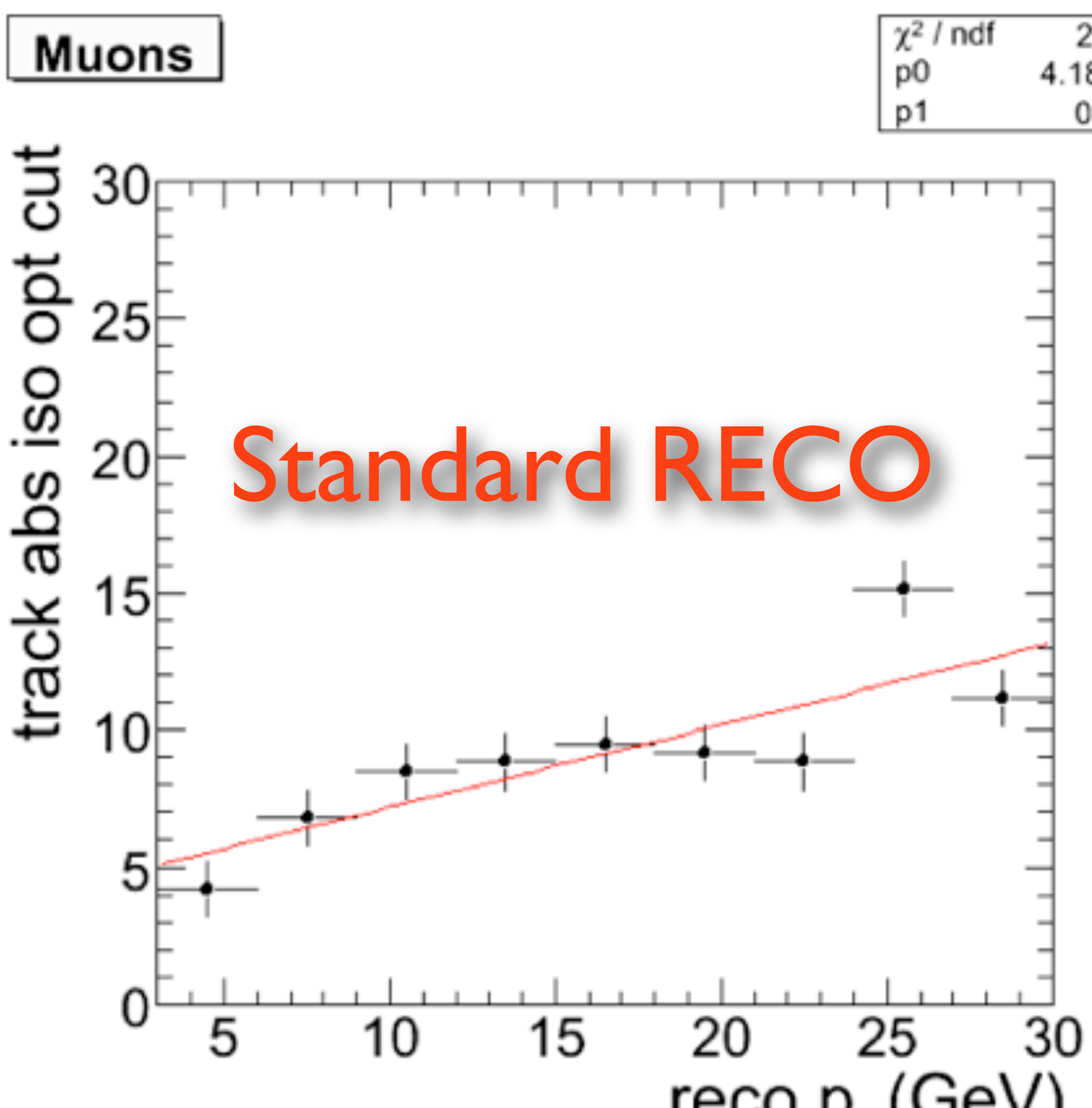


CMS AN 2009/167

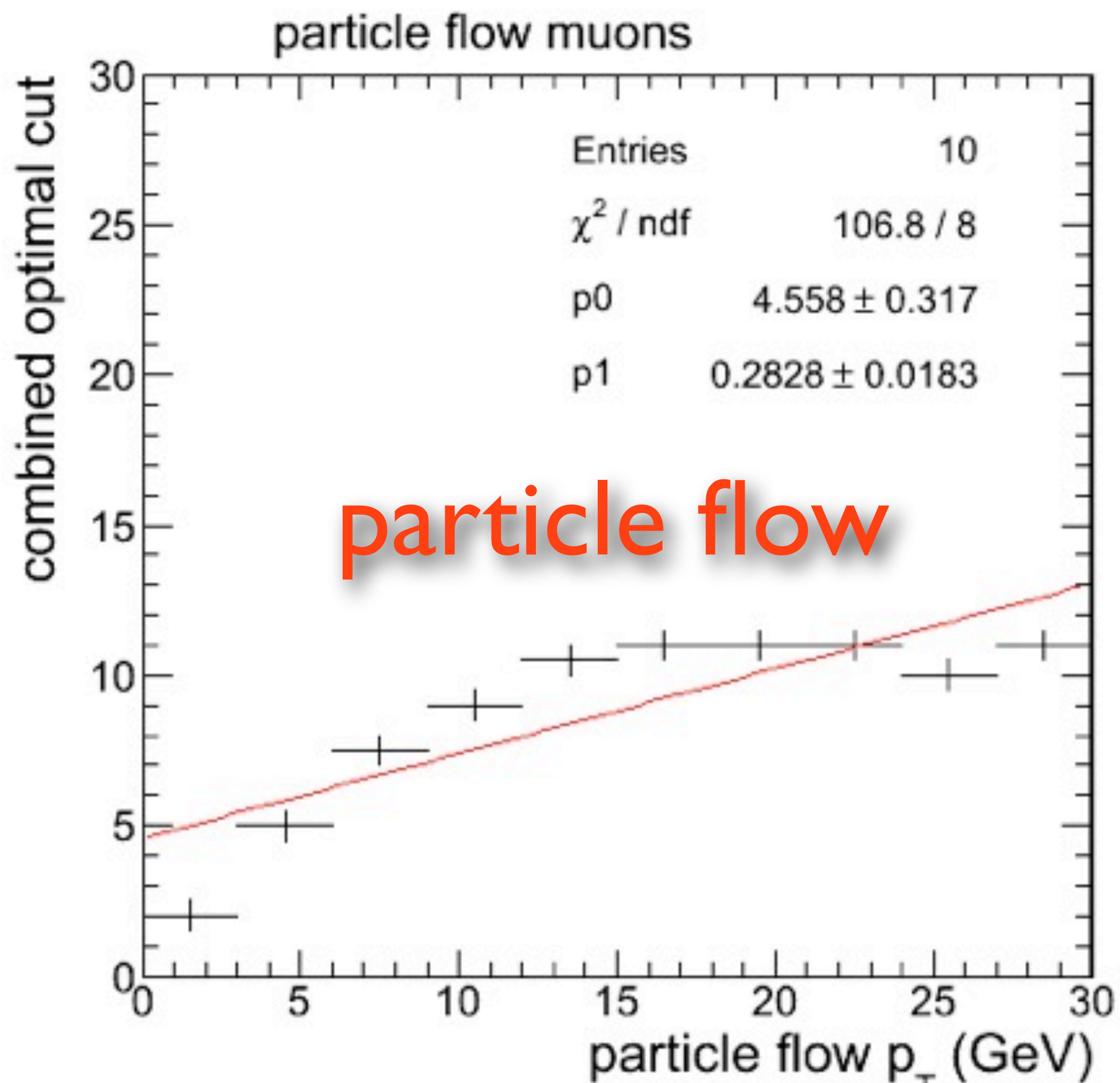


Optimal cut for muons

- **Optimal**
  Minimizes $x = \sqrt{(1 - \text{eff})^2 + (1 - \text{rej}_{\text{fake}})^2}$



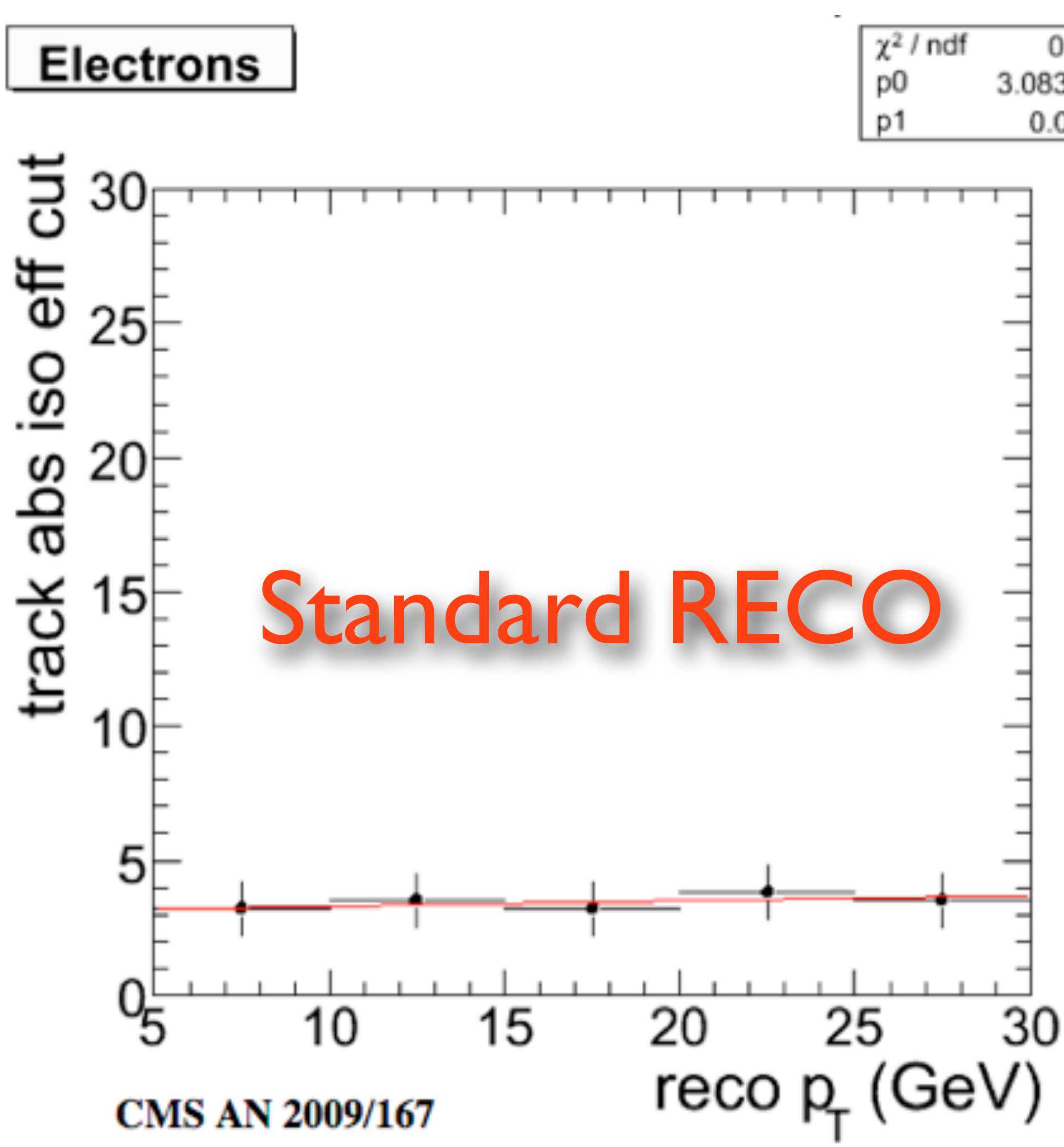
CMS AN 2009/167



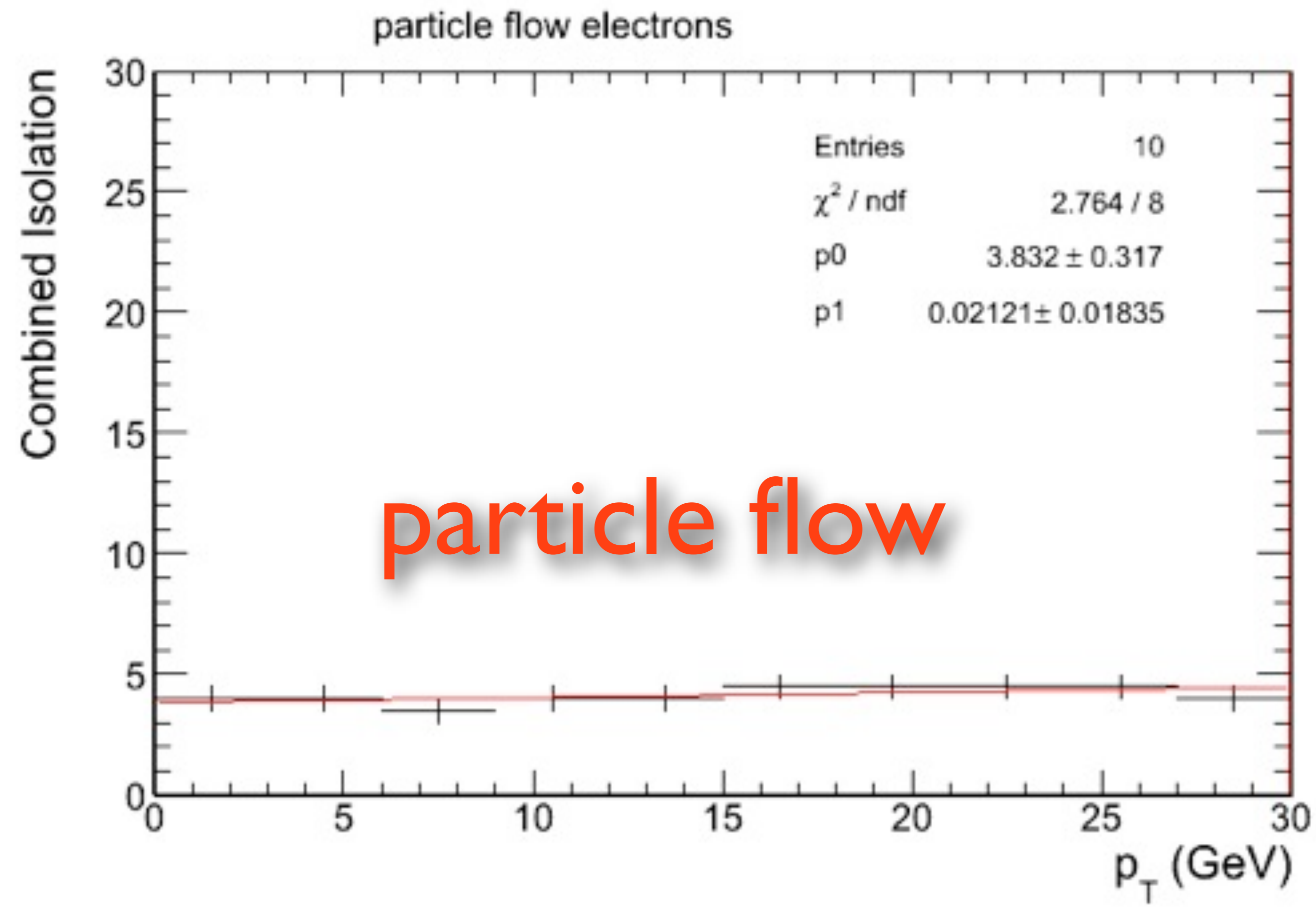
Thursday, 21 January 2010

Efficient cut for electrons

- **Efficient**
  Lowest cut on isolation at which $\text{eff}_{\text{prompt}} \geq 0.9$

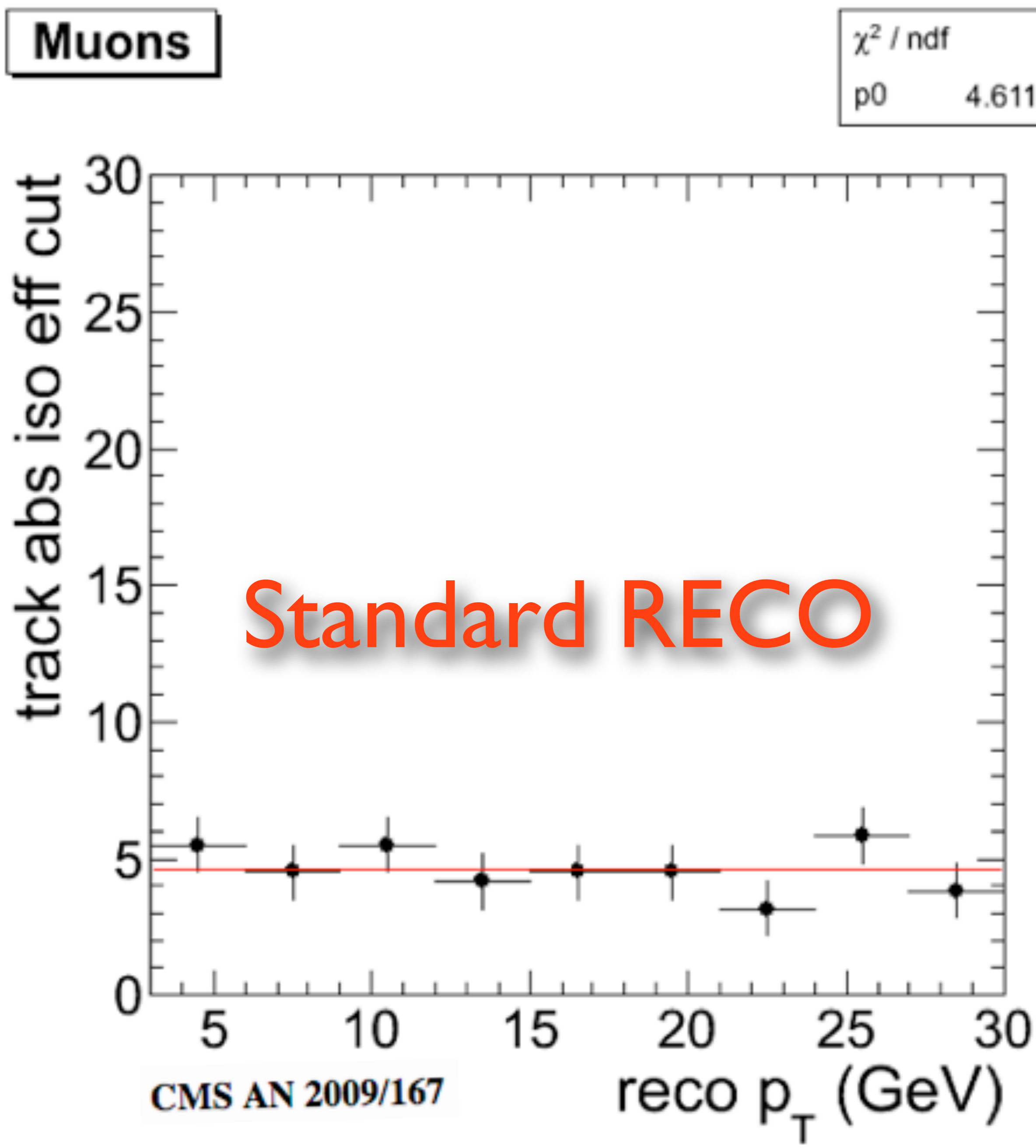


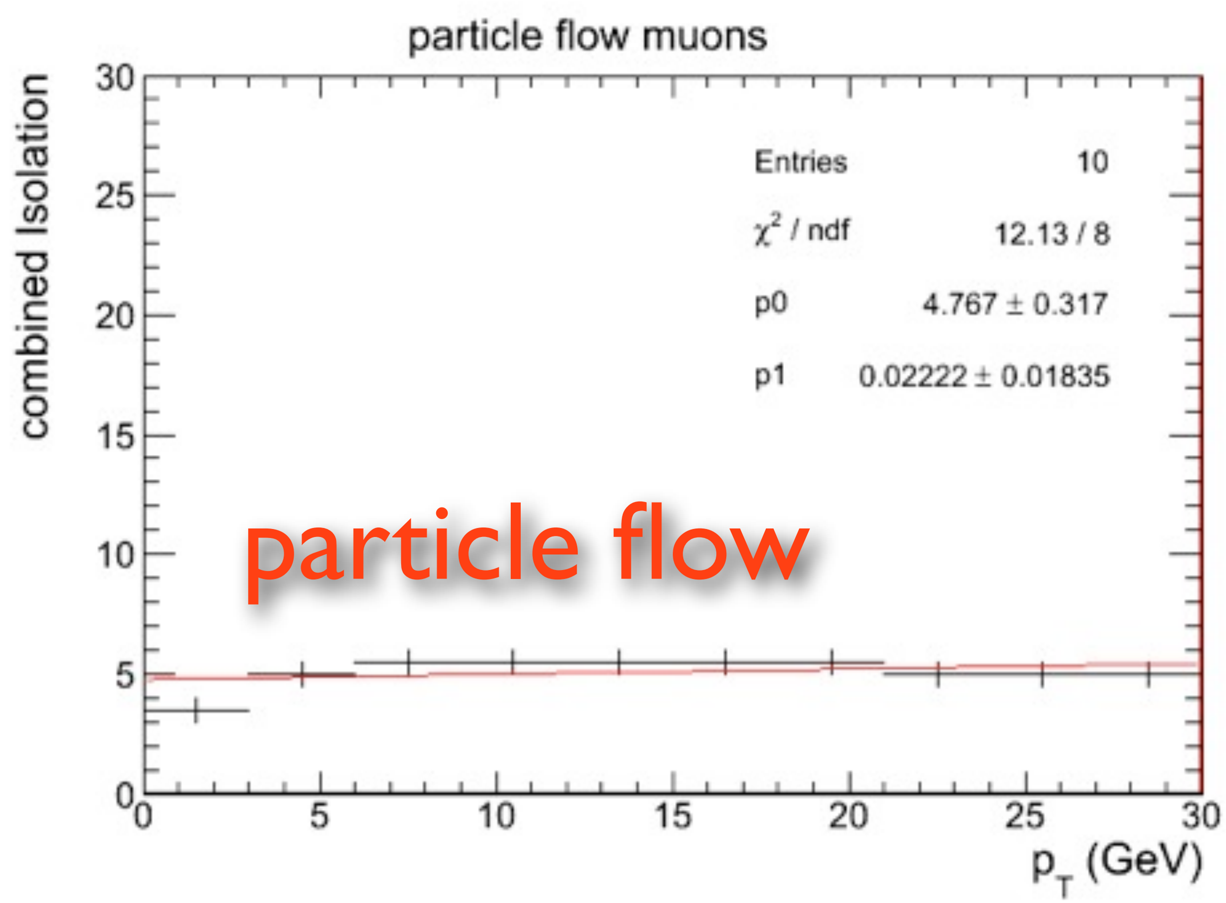
CMS AN 2009/167



Efficient cut for muons

- **Efficient**
  Lowest cut on isolation at which $\mathrm{eff}_{prompt} \geq 0.9$





Single Lepton

Applying the optimal cuts to a SUSY simple single lepton selection...

- Number of leptons = 1
- Number of Jets ≥ 3
- Transverse energy of the Jets > 50 GeV
- CaloMET > 100 GeV
  - V+jets recommendations or...
  - Optimal cut for combined(PF2PAT) and track isolation(PAT).

Combined Relative Isolation

$$\frac{EcalIso + HcalIso + TrkIso}{p_T^{\mu}}$$

Standard RECO

$$\frac{\text{IsoChargedHadron + IsoNeutralHadron + isoPhoton}}{p_T^{\mu}}$$

particle flow

Muon Selection

- Globalized normalized $\chi^2 < 10$
- |d0| < 2 mm
- tracker hits ≥ 11
- Et in HCAL vet cone < 6 GeV
- Et in ECAL veto cone < 4 GeV
- Combined Relative Isolation < 0.1

Electron Selection

- eidTight Electrons
- |d0| < 2 mm
- Combined Relative Isolation < 0.1

to obtain...

Single Lepton

Summary Table at 7 TeV PAT.

Sample	e				mu			
	V+j pt10	SL opt:pt10	SL opt:pt5	SL opt:pt2	V+j pt10	SL opt:pt10	SL opt:pt5	SL opt:pt2
LM0	96.14	114.64	116.86	117.07	119.53	161.15	199.24	212.56
LM1	14.43	16.68	17.52	17.55	17.36	21.41	29.42	31.97
QCD 250-500	0	0	0	0	0	0	108.39	180.65
QCD 500-1000	0	2.86	4.28	4.28	1.43	9.99	42.85	59.99
QCD 10000-Inf	0.1	0.15	0.15	0.15	0.1	1.4	3.58	5.08
bb pt30	0	0	0	0	0	0	0	0
tt + jets	88.27	99.71	100.91	100.97	87.32	104.93	119.11	123.73
w+ jets	146.31	162.94	162.94	162.94	56.53	71.49	79.80	83.13
$S/\sqrt{B}$ LM0	6.26	7.03	7.13	7.15	9.91	11.76	10.59	9.99
$S/\sqrt{B}$ LM1	0.94	1.02	1.06	1.07	1.44	1.56	1.56	1.50

Summary Table at 7 TeV PF2PAT.

Sample	e				mu			
	V+j pt10	SL opt:pt10	SL opt:pt5	SL opt:pt2	V+j pt10	SL opt:pt10	SL opt:pt5	SL opt:pt2
LM0	66.60	60.40	61.78	61.86	88.02	113.10	136.75	144.39
LM1	9.2	9.034	9.69	9.716	12.95	16.40	22.25	23.94
QCD 250-500	0	0	0	0	0	0	0	0
QCD 500-1000	0	0	2.37	2.37	2.37	4.74	14.22	18.96
QCD 10000-Inf	0	0	0	0	0.22	0.33	0.66	1.2
bb	0	0	0	0	0	0	0	0
tt + jets	31.15	28.62	29.16	29.21	42.36	52.05	58.40	60.33
w+ jets	33.03	30.68	30.68	30.68	33.03	33.03	43.20	43.20
$S/\sqrt{B}$ LM0	8.31	7.84	7.83	7.84	9.97	11.91	12.67	12.98
$S/\sqrt{B}$ LM1	1.15	1.19	1.23	1.23	1.477	1.72	2.06	2.15

Cross Sections at 7 TeV.

Sample	σ (pb)
LM0	38.93
LM1	4.88
QCD, 250 < pt < 500 GeV	171000
QCD, 500 < pt < 1000 GeV	5200
QCD, 1000 < pt < Inf GeV	83
W+ jets	17830
tt + jets	90
bb pt 30	60411000.0

Double lepton Selection

- MET trigger (MET > 50 GeV)
- $MH_T > 50$ GeV
- $H_T > 350$ GeV

Same Sign

Number of Leptons = 2
First and Second Lepton should have the same charge

Opposite Sign

Number of Leptons = 2
First and Second Lepton should have the opposite charge

Results are ....

Same Sign Double Lepton

Sample	e e				mu mu				e mu			
	V+j pt10	opt:pt10	opt:pt5	opt:pt2	V+j pt10	opt:pt10	opt:pt5	opt:pt2	V+j pt10	opt:pt10	opt:pt5	opt:pt2
LM0	1.381	1.045	1.119	1.119	1.828	3.134	6.158	6.195	2.388	2.817	3.751	4.310
LM1	0.278	0.246	0.28	0.28	0.371	0.644	1.405	1.416	0.638	0.753	1.087	1.189
QCD 250-500	0	0	0	0	0	0	0	0	0	0	0	0
QCD 500-1000	0	0	0	0	0	0	7.001	7.001	0	0	0	0
QCD 10000-Inf	0	0	0	0	0	0	0	0	0	0	0	0
bb	0	0	0	0	0	0	0	0	0	0	0	0
tt + jets	0.193	0.144	0.193	0.193	0.032	0.257	1.141	1.157	0.16	0.273	0.595	0.884
w+ jets	0	0	0	0	0	0	0	0	0	0	0	0
S/√B LM0	3.143	2.753	2.547	2.547	10.219	6.184	2.158	2.169	5.97	5.391	4.863	4.584
S/√B LM1	0.633	0.648	0.637	0.637	2.074	1.27	0.492	0.496	1.595	1.441	1.409	1.265

Particle Flow

Standard RECO

Sample	e e				mu mu				e mu			
	V+j pt10	opt:pt10	opt:pt5	opt:pt2	V+j pt10	opt:pt10	opt:pt5	opt:pt2	V+j pt10	opt:pt10	opt:pt5	opt:pt2
LM0	1.36	2.06	2.184	2.205	2.679	5.42	10.881	10.943	2.761	5.935	7.955	9.171
LM1	0.223	0.381	0.421	0.421	0.519	0.817	1.893	1.913	0.672	1.049	1.514	1.703
QCD 250-500	0	0	0	0	0	0	0	0	0	0	0	0
QCD 500-1000	0	0	0	0	0	0	0	0	0	0	0	0
QCD 10000-Inf	0	0	0	0	0	0	0	0.043	0	0	0	0
bb	0	0	0	0	0	0	0	0	0	0	0	0
tt + jets	0.255	0.501	0.543	0.543	0.021	1.257	3.398	3.43	0.362	2.056	3.899	5.156
w+ jets	0	0	0	0	0	0	0	0	0	0	1.666	1.666
S/√B LM0	2.693	2.91	2.964	2.992	18.486	4.834	5.902	5.872	4.589	4.139	3.372	3.511
S/√B LM1	0.441	0.538	0.571	0.571	3.581	0.729	1.027	1.026	1.117	0.731	0.642	0.652

Opposite Sign Double Lepton

Sample	e e				mu mu				e mu			
	V+j pt10	opt:pt10	opt:pt5	opt:pt2	V+j pt10	opt:pt10	opt:pt5	opt:pt2	V+j pt10	opt:pt10	opt:pt5	opt:pt2
LM0	7.533	6.557	6.836	6.836	11.539	16.92	23.238	23.297	8.289	10.244	12.177	13.074
LM1	2.379	2.072	2.148	2.148	3.489	4.515	6.184	6.198	1.115	1.341	1.965	2.157
QCD 250-500	0	0	0	0	0	0	0	0	0	0	0	0
QCD 500-1000	0	0	0	0	0	0	0	0	0	0	0	0
QCD 10000-Inf	0	0	0	0	0	0	0.094	0.094	0	0	0	0
bb	0	0	0	0	0	0	0	0	0	0	0	0
tt + jets	3.05	2.352	2.401	2.401	4.38	5.905	7.317	7.333	7.138	6.878	7.495	7.787
w+ jets	0	0	0	0	0	0	0	0	0	0	0	0
S/√B LM0	4.313	4.275	4.412	4.412	5.513	6.963	8.536	8.548	3.102	3.906	4.448	4.685
S/√B LM1	1.362	1.351	1.386	1.386	1.667	1.858	2.271	2.274	0.417	0.511	0.717	0.773

Particle Flow

Standard RECO

Sample	e e				mu mu				e mu			
	V+j pt10	opt:pt10	opt:pt5	opt:pt2	V+j pt10	opt:pt10	opt:pt5	opt:pt2	V+j pt10	opt:pt10	opt:pt5	opt:pt2
LM0	8.016	11.407	11.799	11.799	14.013	21.167	31.555	31.673	10.505	16.287	20.423	21.932
LM1	2.156	2.772	2.872	2.874	4.162	5.327	7.503	7.519	1.160	1.872	2.729	3.015
QCD 250-500	0	0	0	0	0	0	0	0	0	0	0	0
QCD 500-1000	0	0	0	0	0	0	0	0	0	0	0	0
QCD 10000-Inf	0	0.006	0.013	0.013	0	0.019	0.162	0.194	0	0	0.006	0.013
bb	0	0	0	0	0	0	0	0	0	0	0	0
tt + jets	11.336	12.276	12.5	12.511	5.962	8.376	11.902	11.998	19.509	24.231	27.457	29.145
w+ jets	0	0	0	0	0	0	1.67	1.67	0	0	0	0
S/√B LM0	2.380	3.255	3.338	3.334	5.739	7.305	8.515	8.507	2.378	3.308	3.897	4.061
S/√B LM1	0.64	0.791	0.812	0.812	1.704	1.838	2.024	2.019	0.262	0.38	0.52	0.558

Conclusions

- Efforts to improve particle flow reconstructions are being made. (http://indico.cern.ch/getFile.py/access?contribId=5&resId=0&materialId=slides&confId=76306) This kind of studies can open the doors to improvements in our results.
- Further optimisations of isolation parameters are still possible and will be done.
- Particle Flow leptons are almost perfectly isolated for prompt leptons, this is due to the isolation definition in particle flow.
- For a single lepton very simple selection, an improvement in the significance using particle flow candidates is evident comparing to standard reco candidates.
- For a same sign di-lepton very simple selection, no improvement can be seen, however the low statistics may have an important roll explaining these results
- For an opposite sign di-lepton very simple selection, a small improvement in the significance can be seen.
- This first approach was done using a default particle flow configuration, results coming "out of the box" are already encouraging.
- We are planning to write an analysis note using this work